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Cumulative Summation Test for Learning Curve (LC-CUSUM) in Labia Majora Plasty

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ABSTRACT

Purpose: To evaluate the learning curve of labium majora plasty using the learning curve cumulative summation (LC-CUSUM) method and to determine the number of procedures required to achieve surgical proficiency.

Methods: This retrospective study analyzed 120 consecutive labium majora plasty procedures performed by three obstetrics and gynecology specialists with no prior experience in cosmetic gynecology. All trainees completed a standardized hands-on training course before independently performing procedures in their own clinics. Each trainee's first 40 cases were evaluated. Surgical success and failure were defined based on postoperative complications, need for revision, and patient dissatisfaction. LC-CUSUM analysis was applied using predefined acceptable (3%) and unacceptable (10%) failure rates. Continuous variables were analyzed using analysis of variance, and categorical variables using chi-square or Fisher's exact test.

Results: A total of 120 patients were included (40 per trainee). Patient demographics and procedural characteristics were comparable among the three groups ($p>0.05$). Failure rates were 5% (n=2), 7.5% (n=3), and 5% (n=2) for trainees 1, 2, and 3, respectively. LC-CUSUM analysis demonstrated that all trainees achieved acceptable performance levels within the study period. Competency thresholds were reached after 9, 21, and 16 procedures for trainees 1, 2, and 3, respectively.

Conclusion: Patient demographics, procedure characteristics, and outcome measures were comparable among the three trainees. LC-CUSUM charts demonstrated that all trainees achieved adequate performance levels during the observation period. Competency thresholds were reached after 9, 21, and 16 procedures for the three trainees indicating variability in individual learning curves.

Keywords: Labium majora plasty, cosmetic gynecology, surgical outcomes, learning curve, training assessment

INTRODUCTION

Labia majora plasty is an effective procedure used to correct asymmetry, deformities, and volume loss of the labia majora associated with aging.[1] This procedure has recently become increasingly popular among patients.[2]

There has been an increase in demand for labia majora plasty surgery, based on the belief that improving vulvar aesthetics may enhance sexual well-being and self-confidence.[3] The loss of dermal collagen and the signs of aging in the labia majora due to gravity lead to skin wrinkles known as sagging, causing a loss of volume and a changed appearance in the labia majora and minora. This creates a discrepancy in size and shape between the two lips, moving them away from their ideal look and resulting in an unattractive appearance.[4] Although labia majora plasty has a low complication rate, hematoma, infection, and fat necrosis may occur.[5]

Although labiaplasty, fat injection, and fat harvesting are not part of the gynecology and obstetrics training program in Turkey, recent patient demand for these procedures has led to their inclusion in specialty training programs.[6] The skill to perform effective surgery is typically gained through a master-apprentice relationship under the supervision of experienced surgeons. However, objectively assessing a trainee's surgical competence and learning ability can be difficult. The learning process varies depending on the individual skills of the

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trainee, the teaching methods used by the instructor, and the institutional environment.[7] Different methods can be employed to evaluate whether a trainee has reached the required level of competence. While performing a certain number of supervised procedures is a common practice, this method fails to account for individual differences.[8] As a solution to this issue, a statistical tool called the learning curve cumulative summation (LC-CUSUM) test has been developed to assess when a procedure has been sufficiently mastered. LC-CUSUM is designed to determine whether a predefined performance level has been achieved and provides intuitive graphical representations, as well as the capability to detect even small, ongoing changes in performance.[8] The aim of this study was to assess the learning curve for labia majora plasty using the LC-CUSUM method and to determine the number of procedures required to achieve surgical competence.

METHODS

A total of 120 labia majora plasty cases involving three trainees were examined retrospectively. All trainees were obstetrics and gynecology specialists who had never performed cosmetic gynecology procedures, including labia majora reduction, labia majora fat grafting, or both. Initially, all trainees attended a hands-on, live surgery course on the first day, which included a four-hour theoretical session on vulvar and lower abdominal anatomy, patient selection, obtaining patient consent, and techniques of labia majora plasty, fat harvesting, microfat preparation, and lipofilling. A two-hour video demonstration of all methods, including discussions of tips and tricks, was completed after the theoretical session. On the second day of the course, the three trainees both performed and assisted with hands-on labia majora plasty, fat harvesting, microfat graft preparation, and vulvar lipofilling on three patients. Then, the trainees returned to their clinics to perform cosmetic surgery procedures. Their first five procedures were reviewed by the same expert, who has more than ten years of experience in cosmetic surgery. Three years after the course, the trainees were contacted and invited to participate in the study. All agreed to send information on their first 40 consecutive cases of labia majora plasty, including surgical labia majora reduction, lipofilling, or a combination of both procedures. Patient files were reviewed for demographic variables, preoperative, one-month, and six-month postoperative photographs, patient satisfaction, and the need for additional fat grafting or revision surgery.

Postoperative photographic outcomes were assessed by independent reviewers who were blinded to the identity of the trainees and the chronological order of the procedures to reduce assessment bias.

Ethical Approval

Ethical approval for this study was obtained from the Bandırma Onyedi Eylül University Non-Interventional Research Ethics Committee (approval number: 2026-01-14, date: 21.01.2026). The study assessed surgical performance using cumulative summation (CUSUM) analysis without modifying standard patient care. All procedures adhered to institutional standards and the Declaration of Helsinki. Written informed consent was obtained from all patients prior to participation in the study.

Patient Selection and Techniques

Patients admitted for labia majora plasty for cosmetic reasons were classified according to Fasola and Gazzola.[9] Briefly, mild labia majora hypotrophy involves no to mild skin thinning and visible fine wrinkles. Cases with mild hypotrophy were excluded because they received hyaluronic acid filler and mesotherapy. Moderate labia majora hypotrophy includes moderate skin laxity and dermatochalasis with visible wrinkles; these cases were treated with microfat lipofilling. Severe labia majora hypotrophy involves severe dermatochalasis and deep wrinkles; these cases first underwent surgical resection of excess vulvar skin followed by lipofilling to enhance the vulva. The skin of the labia majora was reduced on both sides with semilunar vertical incisions along the lateral labial sulcus and medial border of the labia majora, as described by Miklos and Moore.[10] Fat harvesting was performed from the lower abdomen or medial thigh under anesthesia using a Coleman cannula connected to a 20 mL luer-lock syringe. Under low negative pressure, 30 to 50 mL of fat was harvested using a dry technique. The emulsification of the microfat was achieved by shifting tissue between two 20 cc syringes connected by a female-to-female luer-lock connector. After more than 30 passes, a final 600-micrometer filter was used to obtain microfat and stromal vascular fraction. The prepared microfat suspensions were transferred to a one cc syringe and grafted to each labia majora by a one-point entry and a retrograde technique through one point at the top of each labia majora, as described by Menkes et al.[11]

Statistical Analysis

We previously reported that the complication rate in genital cosmetic procedures was 2.7% (72/2594).[12] An acceptable failure rate was established at 3% (p_0=0.03), while an unacceptable failure rate was set at 10% (p_1=0.10). As noted earlier, the acceptable level of type I error was α=0.05 (the chance of incorrectly claiming the trainee is competent), and of type II error was β=0.20 (the chance of wrongly rejecting the trainee's competency). Based on previously published data, the success sample weight X=0 was calculated at 0.0080043, and failure sample weight X=1 was -1.38629. The average run length was 40, with a decision interval h of 2.5.[8,13-15] Comparison of variables was conducted using the chi-square test for categorical variables and Fisher's exact test. Analysis of variance was used for continuous variables among the three operators. A p value <0.05 was considered statistically significant.

RESULTS

A total of 120 patients were analyzed, with 40 cases per trainee. The mean age ranged from 36.7±7.5 to 40.3±9.3 years, and the mean body mass index ranged from 28.6±3.3 to 30.3±3.9 kg/m^2, with no significant differences between groups (p>0.05). Similarly, the distribution of labia majora hypotrophy severity and the types of procedures performed were comparable between the three trainees (p>0.05) (Table 1).

The overall unfavorable outcome rate was 5.8% (7/120). Unfavorable outcome included hematoma in two patient

Table 1. Patient and intervention characteristics in three trainees

Patient characteristics	Trainee 1 n=40	Trainee 2 n=40	Trainee 3 n=40	*p*
Age (years)	39.7±8.1	36.7±7.5	40.3±9.3	0.12
Body mass index (kg/m²)	28.6±3.3	30.3±3.9	29.5±4.9	0.19
Labia majora hypotrophy				
Moderate	17 (42.5%)	16 (40%)	13 (32.5%)	0.6
Severe	23 (57.5%)	24 (60%)	27 (67.5%)	
Labia majora reduction	23 (57.5%)	24 (60%)	27 (67.5%)	0.6
Labia majora lipid grefting	40 (100%)	40 (100%)	40 (100%)	0.6
Unfavorable outcome	2 (5%)	3 (7.5%)	2 (5%)	0.8
Labia majora hematoma	1 (2.5%)	1 (2.5%)	-	
Labia majora enfection	-	1 (2.5%)	1 (2.5%)	
Patient aesthetic dissatisfaction	1 (2.5%)	1 (2.5%)	1 (2.5%)	

Data are presented as mean ± SD or n (%). Continuous variables were analyzed using one-way ANOVA and categorical variables using the chi-square or Fisher's exact test, as appropriate. A *p* value <0.05 was considered statistically significant.
ANOVA: Analysis of variance

(1.7%), infection in two patients (1.7%), and patient-reported aesthetic dissatisfaction in three patients (2.5%). No significant differences in unfavorable outcomes were observed between the trainees ($p=0.80$). Failure rates were 5%, 7.5%, and 5% for trainees 1,2, and 3, respectively.

LC-CUSUM analysis demonstrated that all trainees achieved acceptable performance levels within the study period. Competency thresholds were reached after 9, 21, and 16 procedures for trainees 1, 2, and 3, respectively (Figure 1).

DISCUSSION

This study demonstrates the applicability of the LC-CUSUM method for tracking the learning curve of labia majora plasty and for evaluating the acquisition of surgical proficiency. It is important to bring a new surgical procedure to a standardized and implementable level for surgeons in training; otherwise, this process could lead to irreversible results. Therefore, trainees should be monitored until they can perform the surgical procedure independently. However, objectively assessing trainees' proficiency levels in surgical procedures is challenging. Factors such as the number and duration of procedures, the trainee, instructor, the environment where the course is conducted, and the course content all influence this assessment. The study results indicated that the LC-CUSUM is a sensitive and discriminative tool for evaluating surgical learning curves. Although no significant differences were observed in baseline characteristics or complication rates between the trainees, the number of procedures required to achieve competence varied from nine to 21, a 133% variability. Nonetheless, the varying time required for trainees to reach an optimal performance level in surgical procedures highlights that learning surgical techniques is a dynamic process affected by individual differences. When evaluating the achievement of optimal surgical competence within course content, it appears that methods based solely on the number of procedures performed have limitations.

Issat and colleagues examined whether the LC-CUSUM and competence-CUSUM methods effectively assess the usability of LC-CUSUM and the number of procedures needed to reach an optimal level.[16] This research also highlighted the importance of personalized monitoring systems during training and concluded that LC-CUSUM is suitable for tracking proficiency in surgical procedures after training.

Previous studies have shown that LC-CUSUM can be used to evaluate learning curves in surgical procedures and gynecological imaging, and to assess the learning process of embryo transfer. In the studies by Dessolle et al.[15] it was demonstrated that there was insufficient data regarding the learning processes in assisted reproductive technologies and the learning curve of trainees. Therefore, they recognized the importance of embryo transfer in creating pregnancy using assisted reproductive technologies. By developing a portable model to establish the learning curve of embryo transfer with the LC-CUSUM and CUSUM methods, they showed that this provides a resource to measure continuous learning ability. Moreover, they advocated for personalized training and emphasized that the number of embryo transfers required for a trainee to reach an ideal level of practitioner competence varied depending on the individual. These authors recommended applying the CUSUM method for quality assessment.[15]

The present study identified the number of procedures required for trainees to achieve technical proficiency in labia majora plasty, highlighting differences experienced by trainees in learning curves and emphasizing the need for personalized assessment. It is natural that trainees differ in their proficiency and learning abilities. Therefore, assessing the surgical learning curve on an individual basis is essential. LC-CUSUM serves as a quantitative tool to evaluate learning curves for each person. This method indicates when a set level of learning has been reached and is independent of the total number of procedures performed. Trainees' learning abilities can be tailored through direct observation by the instructor and graphical visualization of the learning curve. Graphical

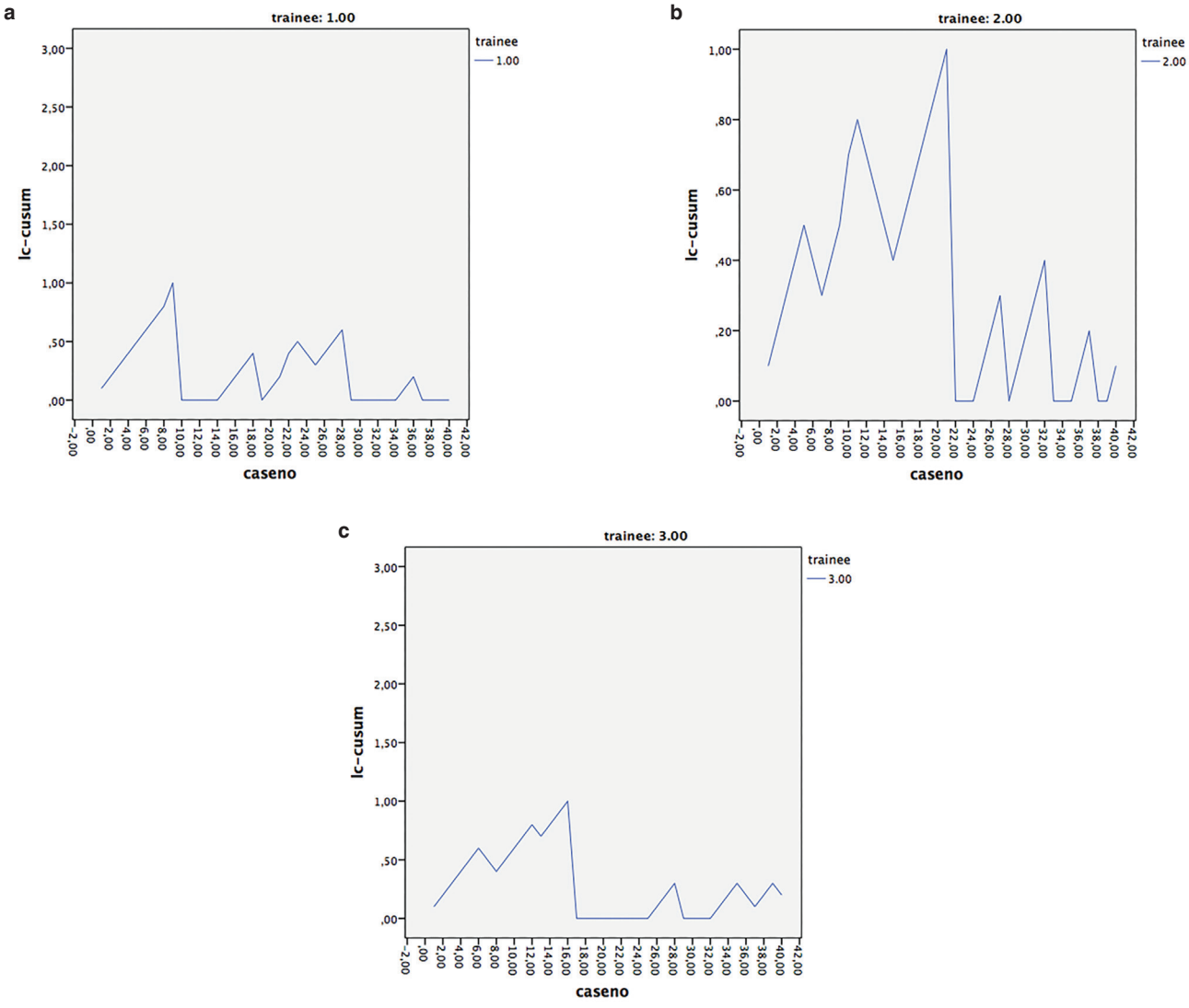

Figure 1. The figure presents the learning curve of cumulative sums for trainee 1 (a), trainee 2 (b), and trainee 3 (c)

monitoring has proven to be effective for the assessment of learning progress curves.[17,18] However, the biggest limitation of this method is the absence of a standardized test or a clearly defined critical point to objectively confirm that the learning curve has reached an acceptable level. The learning abilities of the trainees were compared to those of labia majora plasty trainers, and the LC-CUSUM parameters used in this model were found to be robust. Although establishing threshold values within the LC-CUSUM methodology requires precision, the simplicity of programming and the flexibility inherent in the methodology have made the LC-CUSUM readily accessible to users.

Study Limitations

A key limitation of this study relates to the definition of surgical success and failure within the LC-CUSUM model. In the present analysis, failure was defined based on clinically relevant but indirect outcome measures, including patient satisfaction, the need for revision surgery, and the requirement for additional fat grafting. Although these endpoints reflect real-world clinical decision-making and are commonly used in surgical practice, they inherently include subjective components and are not supported by standardized, validated patient-reported outcome measures (PROMs). The absence of validated assessment tools, such as the genital appearance satisfaction scale, the female sexual function index, or the female genital self-image scale, may limit the objectivity, reproducibility, and discriminatory capacity of the LC-CUSUM analysis. Furthermore, patient satisfaction is influenced by multiple psychosocial and cultural factors, which may introduce variability independent of surgical performance. Therefore, the outcome measures used in this study should be interpreted as surrogate clinical indicators rather than fully standardized endpoints. Future studies incorporating validated PROMs into postoperative assessment protocols would strengthen the methodological robustness of LC-CUSUM-based evaluations and provide a more comprehensive and objective assessment of surgical competence.

The retrospective design of this study is also an important limitation, especially regarding patient satisfaction assessments and postoperative photographic outcomes. Retrospective data collection can introduce both selection and information bias because cases with incomplete records or poor documentation might have been excluded, and outcome assessments may not have been consistently standardized. In addition, the retrospective nature of the analysis might underestimate early variability in surgical performance, particularly during the initial phase of the learning curve, potentially smoothing out fluctuations that would be visible in a prospective setting. A prospectively designed LC-CUSUM application, based on predefined outcome criteria and standardized assessment tools, would offer a more robust and methodologically sound mechanism to evaluate surgical competence. Therefore, future larger prospective LC-CUSUM studies in cosmetic gynecology are needed to better capture real-time performance variations and to improve the validity and reliability of learning curve evaluations.

Although all procedures were performed following a standardized training program under the supervision of a single experienced instructor, which enhances internal consistency, this may limit the external validity of the findings. Learning curves in surgical practice are influenced by multiple contextual factors, including the institutional environment, the technical approach of the trainer, and case-mix characteristics. Therefore, the competency thresholds identified in this study may not be directly generalizable to other training settings. These considerations highlight the need for multicenter studies to validate and refine LC-CUSUM-derived learning curve benchmarks across diverse clinical and educational environments.

The follow-up period in this study was limited to six months, which may not be sufficient to capture long-term outcomes, such as graft retention, delayed revision needs, and sustained patient satisfaction in fat grafting-based procedures. Therefore, the competency achieved as determined by LC-CUSUM should be seen as reflecting early technical skill rather than long-term aesthetic results, and this distinction is important to prevent overinterpreting the results.

The LC-CUSUM parameters used in this study, including the acceptable and unacceptable failure rates, were derived from previously published data in cosmetic surgery and are not specific to labia majora plasty. While these thresholds were selected to provide a pragmatic and literature-based framework for performance evaluation, procedure-specific benchmarks may differ. Therefore, future studies should aim to validate these parameters and consider sensitivity analyses to determine the most appropriate thresholds for labia majora plasty.

CONCLUSION

Given the variability observed in individual learning curves for labia majora plasty, the best approach is to adopt a personalized methodology under the guidance of a professional trainer during the course. In this context, the LC-CUSUM method proved to be a suitable and effective tool for monitoring surgical skill proficiency.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the Bandırma Onyedi Eylül University Non-Interventional Research Ethics Committee (approval number: 2026-01-14, date: 21.01.2026).

Informed Consent: Written informed consent was obtained from all patients for participation and use of their clinical data and images.

Footnotes

Authorship Contributions

Surgical and Medical Practices: E.G., E.H.C., Concept: E.G., E.H.C., Design: E.G., G.K., Data Collection or Processing: E.G., G.K., A.G.E., E.H.C., Analysis or Interpretation: E.G., G.K., A.G.E., Literature Search: E.G., G.K., A.G.E., Writing: E.G.

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