

ASSESSMENT OF OUTCOMES IN DONOR SITE CLOSURE OF ANTEROLATERAL THIGH FLAP WITH KEYSTONE FLAP

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ABSTRACT

Background: After harvesting an anterolateral thigh (ALT) flap, closing the donor site too tightly can lead to problems or require skin grafting, which can impact both the structural and cosmetic results. The Keystone Perforator Island Flap (KPIF) is a reliable alternative to tension-free closure that preserves contour and reduces morbidity.

Objective: To look at the KPIF method for closing the donor site after harvesting a free ALT flap and see how safe, reliable, and attractive it is, as well as its results and problems.

Methodology: This study was conducted from 01 June 2024 to 30 November 2025 (18 months), at the Plastic Surgery Department of Fauji Foundation Hospital, Rawalpindi. This was a prospective descriptive cohort study. The study comprised consecutive patients undergoing donor-site closure for KPIF. In the first two weeks after surgery, the attributes such as demographic information, surgery details, and early postoperative problems were recorded. These problems included seroma, hematoma, epidermolysis, wound dehiscence, flap necrosis, and compartment syndrome. As part of a standard follow-up after three and six months of surgery, patients filled out structured questionnaires and underwent clinical examination. The examination comprised of checking for contour deformity, sensory symptoms like tingling or numbness, differences in thigh circumference compared to the other leg, and evaluating the quality of the scar using the Vancouver Scar Scale.

Results: Our study included 28 patients, with an average age of 41 ± 15 years, an average BMI of 20 ± 1.2 kg/m², and 57.1% of them were women. In all cases, closure without any major complications was achieved. In 14.3% of cases, minor complications were seen and were managed conservatively. Measurements of thigh circumference showed no significant difference compared to the other limb, and most people said they had mild sensory problems. At three months, 85.7% rated the cosmetic results as good or excellent, and 42.9% of the patients as per the structured questionnaire, showed a contour deformity.

Conclusion: Closing the ALT donor site with KPIF is safe, effective, and looks good. It keeps the structure of the site intact and lowers the risk of problems.

Keywords: Morbidity, Perforator Flap, Plastic Surgery, Reconstruction, Treatment Outcomes

INTRODUCTION

The anterolateral thigh (ALT) flap is a flexible and widely used choice in reconstructive surgery because its vascular anatomy is always the same, its soft tissue is flexible, and it can provide a large skin paddle.¹ You can

use it either as fasciocutaneous or a musculocutaneous flap, and it is often used to fix complex defects in the head and neck, trunk, and limbs. Changes to the design, such as the horseshoe shape, make it even more useful for restoring contours and covering large defects. However, optimizing the closure of the donor site is still important because it affects postoperative outcomes.² Despite the ALT flap's generally low donor-site morbidity, several complications have been documented. These involve protracted healing, wound dehiscence, contour irregularities, seroma development, hypertrophic scarring, and sensory disturbances such as lateral thigh paresthesia.

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Functional impairment resulting from quadriceps weakness or musculoskeletal dysfunction is infrequent that can affect postoperative quality of life; however, sensory alterations are considered the most prevalent donor-site complication.^{2,6} Research indicates that the donor-site closure technique significantly influences postoperative outcomes, with primary closure typically associated with expedited healing and superior cosmetic results compared to skin grafting.⁸

With the given complications of wound dehiscence, healing difficulty, contour deformity, seroma, hypertrophic scars, and sensory changes, including lateral thigh numbness of 24% and musculoskeletal dysfunction of 4.8%, the morbidity of the donor site is thus a serious consideration.²

Small skin defects could be easily closed, however, the defects that are over 8 cm require a different method for reconstruction. While the use of local flap advances will increase the complexity of surgery, and this results in additional morbidity. In contrast, the traditional methods, including split-thickness skin grafting (when compared to adjacent native tissue) results in issues like colour differences, counter deformity, and relative mechanical weakness. This happens because they lack full dermal architecture of normal skin and are more prone to the secondary contraction, which compromises durability and contour at the donor site. Several alternative techniques, which involve local advancement flaps, V-Y advancement flaps, perforator-based propeller flaps, and anteromedial thigh flaps, have been suggested to address these constraints and enhance the aesthetic outcomes while reducing the donor-site morbidity.⁵ Recent systematic reviews have also been suggested to use decision-making algorithms to assess the flap width in relation to thigh circumference and it helps to choose the best ways to close the donor site.⁴

One of the technique for ALT flap reconstruction of the donor site is Keystone Perforator Island Flap (KPIF) that is suggested by the Behan et al.⁷ The KPIF is useful as it effectively redistributes the defect with robust vascularity by utilizing adjacent skin from preserved perforators. The benefits of this method are: (i) it reduces healing time, (ii) offers superior color and texture match, (iii) it allows primary closure without grafting, and (iv) it has a low morbidity rate. Although, most of the studies have small sample sizes (i.e., six or less patients), they resulted in good performances and high patient satisfaction.⁹ Despite of their promising results, the literature that is currently available have significant

anomalies like they are retrospective studies, are inconsistent in reporting standardized donor-site outcomes, they are heterogeneous in patient selection, and are variable in choosing flap design. Also the objective assessment tools like Perfusion studies and validated scar scoring systems are rarely used in these studies. Furthermore, the current evidence's generalizability is limited by the dearth of the regional data, especially from South Asia.

The purpose of this study is to assess the safety, effectiveness, and structural and aesthetic results of keystone flap closure for ALT donor sites in Pakistani patients. To improve postoperative recovery, preserving the form, functional performance, and patient quality of life, this research aims to provide region-specific evidence. It supports the keystone flap as a dependable and functionally superior method for donor-site management by utilizing standardized assessment tools and a single-stage tension-free closure technique.

METHODOLOGY

Between 01 June 2024 and 30 November 2025, consecutive patients who underwent donor-site closure with a keystone flap after free ALT flap harvest were enrolled in a prospective study carried out in the Plastic Surgery Department of Fauji Foundation Hospital, Rawalpindi. The Fauji Foundation Hospital's Ethical Review Committee granted ethical approval. On March 20, 2024, the approval was given with reference number 814/RC/FFH/RWP. We prospectively collected information on postoperative complications, operative details, and demographics of these patients.

Inclusion and Exclusion Criteria

For this study, we enrolled adult patients of any gender presenting with ALT donor site defects exceeding 8 cm. We specifically excluded individuals under 18, as well as those with atypical defects resulting from chimeric or multiple perforator flaps. To ensure data integrity, we excluded cases with incomplete records or those lost to follow-up. Furthermore, we omitted patients with systemic conditions that hinder healing—such as uncontrolled diabetes, chronic kidney disease, or long-term steroid use—alongside any cases where the site was closed using alternative methods like skin grafting or local flaps. We identified participants through a consecutive convenience sampling protocol, ensuring that every patient receiving an anterolateral thigh (ALT) flap with KPIF donor site reconstruction during the study period was evaluated for eligibility. Our team recorded everything from demographic data to specific

surgical findings and recovery milestones using a standardized template. Only cases that aligned perfectly with our inclusion criteria made it into the final analysis.

Sample Size and Consent

Between June 2024 and November 2025, we consecutively enrolled all patients undergoing ALT flap reconstruction. Out of this group, 28 individuals met the inclusion criteria. While this sample size might seem modest, it reflects our entire clinical volume for the 18-month period, driven by the specialized nature of the surgery and the specific requirement for Keystone donor site closure. We believe this prospective descriptive series provides a representative look at the feasibility, safety, and clinical outcomes of the reconstructive technique in this specific context. Every participant gave their informed consent.

Surgical Technique

Before the procedure, we used a handheld Doppler to map out the cutaneous perforators in the anterolateral thigh. For every procedure, we utilized a two-team approach to keep the workflow moving efficiently. Once the ALT flap was elevated and the vascular pedicle was carefully isolated and split, the flap was transferred to the recipient site. While the primary reconstructive team managed the inset and microvascular anastomosis, a second surgical team worked simultaneously to reconstruct the donor-site defect.

Following flap harvest, the donor-site defect was evaluated and, if necessary, transformed into an elliptical shape. A sterile ruler was used to measure the defect's transverse width. Along the line of maximum skin laxity, a keystone perforator island flap had been designed next to the defect's medial edge. The keystone flap's width is almost identical to the donor-site defect's width. The two vertical limbs of the keystone flap were marked at an angle of 90 degrees perpendicular to the defect's medial margin.

Skin incisions were made down to the deep fascia along the flap's designated borders. To increase flap mobility and preserve vascular reliability, a Type IIA modification⁴ of the keystone perforator island flap was used. To make it easier for the flap to advance, the deep fascia was split along its edges. To improve flap mobility while maintaining the integrity of the perforator blood supply, limited undermining beneath the fascia was carried out. The keystone flap's lateral limbs were then moved in the direction of the central defect, allowing tension to be redistributed throughout the surrounding tissue. This allowed for additional tissue advancement

and tension-free donor site closure. Layered wound closure was frequently preceded by the installation of closed-suction drains.

Donor-site closure using the keystone flap required an average operative time of approximately 45 minutes. However, because the donor-site reconstruction was performed concurrently with flap inset and microvascular anastomosis by the primary surgical team, the technique did not increase the overall operative time.

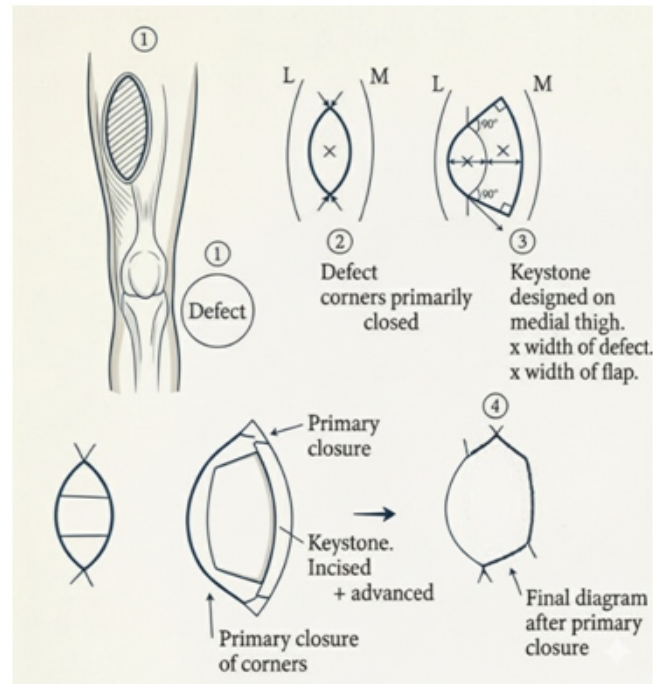


Figure 1: Donor site defect, advancement, and outcome of the keystone flap procedure

Closure was considered successful if the donor site was sealed with viable tissue, preserved thigh contour, and did not require split-thickness skin grafting or secondary revision procedures. Figure 1 is the general illustration of the procedure of keystone flap to the donor site used in the proposed architecture.

Postoperative Assessment

To gauge the success of the procedure, we looked at a mix of clinical, structural, and aesthetic markers. From a clinical standpoint, the primary goal was a tension-free closure at the donor site. We tracked patient outcomes across two distinct phases. In the first two weeks, our focus remained on flap viability and wound healing, specifically monitoring for issues like hematoma, seroma, or partial necrosis. Later on, at the three and six-month marks, we evaluated more permanent results. These included assessing contour deformities, checking for sensory changes like numbness and measuring thigh

circumference relative to the unaffected limb. Scar quality was also formally graded using the Vancouver Scar Scale.

Patients completed structured questionnaires and a clinical examination as part of a standard follow-up at three and six months. Tingling, contour deformity, thigh circumference and scar quality were among the results. Both the operated and contralateral limbs had their thighs measured at a standardized level (15 cm proximal to the superior patellar border); a difference of more than 2 cm was considered a significant deformity.

The Vancouver Scar Scale (VSS) was used to score scar quality; total scores are classified as Excellent (0–3), Good (4–6), or Moderate (7–9). Clinical photos that were standardized were acquired. One plastic surgery fellow with at least three years of post-fellowship experience conducted all evaluations to minimize interobserver variability. For statistical analysis, medians were found for continuous data and frequencies and percentages were computed for patient characteristics and other categorical variables. The Statistical Package for the Social Sciences (SPSS version 23.0, Inc., Chicago, IL) was used for all analysis.



Patient 1

A 56-year-old female (BMI 23 kg/m²) known case of giant cell tumor of knee joint who underwent right sided ALT flap harvest. (A) The resulting donor-site defect measured approximately 17 x 11.6 cm. (B) The defect was reconstructed using a keystone perforator island flap, based on medial cutaneous perforators, allowing for tension-free primary closure. (C) six-month postoperative follow-up.



Patient 2

A 21-year-old female (BMI 19.4 kg/m²) with Post Burn scarring right hand underwent left ALT flap harvest. (A) The resulting donor-site defect measured approximately 15 x 9.5 cm. (B) The defect was reconstructed using a keystone perforator island flap, based on medial cutaneous perforators, allowing for tension-free primary closure. (C) three-month postoperative follow.



Patient 3

A 58-year-old female patient with hypertension (BMI 19.4 kg/m²) who had a dorsal left foot defect following a car accident. (A) the resulting donorsite defect was about 16 by 11 cm in size. (B) Reconstruction based on medial cutaneous perforators using a keystone perforator island flap. (C). A six-month follow-up demonstrates stable healing and scar maturation.

Figure 2: Pre-operative, Post-operative stages of three patients

Microsoft Excel 2016 was used to create the tables and figures. The following figure 2 shows the pre-operative and post-operative recovery stages of three patients.

RESULTS

This prospective study included 28 patients in total. The average body mass index (BMI) was 20.5 kg/m² (± 1.2), and the average age was 41.1 years (± 15.8). Males (42.9%, n=12) were slightly outnumbered by females (57.1%, n=16) in the gender distribution. In terms of comorbidities, over half of the patients (57.1%) had no

serious systemic illness and were in good medical health. With 28.6% of patients having hypertension and 14.3% having diabetes mellitus while hypertension was the most common comorbidity.

The average width and height of the anterolateral thigh flap donor site defects were 10.2 cm and 15.7 cm, respectively. Interestingly, female patients had slightly larger defects (mean 16.75 $\times$ 10.75 cm) than male

Table I: Patient Demographics

Demographics	Mean $\pm$ SD
Age (years)	41.14 $\pm$ 15.83
BMI (kg/m ²)	20.5 $\pm$ 1.24
Gender	
Male n (%)	12 (42.9%)
Female n (%)	14 (57.1)
Comorbidity	
None n (%)	16 (57.1%)
Diabetes n (%)	4 (14.3%)
Hypertension n (%)	8 (28.6%)

Table II: Dimensions of Defects

Gender		Height (cm)	Width (cm)
Male	Mean	14.333	9.5
	N	12	12
	Std. Deviation	0.4924	1.1282
Female	Mean	16.750	10.750
	N	16	16
	Std. Deviation	0.8563	0.8563
Total	Mean	15.714	10.214
	N	28	28
	Std. Deviation	1.4105	1.1501

patients (mean 14.3×9.5 cm) when the data were stratified by gender. Even though it does not involve data with a statistical evaluation, this discrepancy is important as it displays anatomical variability that can influence the management of the donor site.

A successful closure was achieved with the keystone flap in closing the donor site in all 28 cases, thereby providing an overall success rate of 100% flap closure. Also, there was no case that had necrosis or compartment syndrome in this series. The absence of major complications is an important factor that indicates efficacy.

A small number of patients (14.3% of participants; $n=4$) experienced minor complications. These included the development of seromas or hematomas, partial wound dehiscence, and epidermolysis. Notably, in each case, these complications were self-limiting or manageable with conservative care such as drainage, dressings, and wound care, and did not necessitate reoperation.

Table III: Closure of Anterolateral Thigh Flap Donor Site through Keystone Flap

Outcomes	Frequency	% age
Hematoma/seroma		
Yes	04	14.3 %
No	24	85.7 %
Total	28	100 %
Partial dehiscence		
Yes	04	14.3 %
No	24	85.7 %
Total	28	100 %
Epidermolysis		
Yes	04	14.3 %
No	24	85.7 %
Total	28	100 %
Compartment syndrome		
Yes	0	0 %
No	28	100 %
Flap necrosis		
Yes	0	0 %
No	28	100 %

A thorough evaluation at three months was done to assess the donor-site morbidity. Eight patients (28.6%) experienced major tingling sensation, that is indicative of slight sensory alterations at the donor site (Figure 3, whereas twenty-one patients (71.4%) experienced it to a mild extent. These findings suggest that although the symptom of sensory disturbance is not uncommon, the severity is likely to be minimal.

A total of twelve patients (42.9%) had a donor site bulge. Nevertheless, objective measurement did not show any measurable difference in the thigh dimensions in the operated limb and the opposite, unoperated limb. The tissue-advancement procedure provided a very good restoration of the contours without creating any appreciable asymmetry in the shape and dimensions. Not a single patient fulfilled the objective criteria for appreciable deformity, i.e., > 2 cm difference. At the cosmetic evaluation, a very high satisfaction rate at the donor site was obtained. "Excellent" results were observed in eight patients (28.6%), and "Good" results in sixteen patients (57.1%). "Moderate" results were found in only four patients (14.3%). These findings make it certain that the keystone flap procures a very good cosmetic result. The standardized photographs at the follow-up appointment, depicting well-formed scar and intact contour, validated the results.

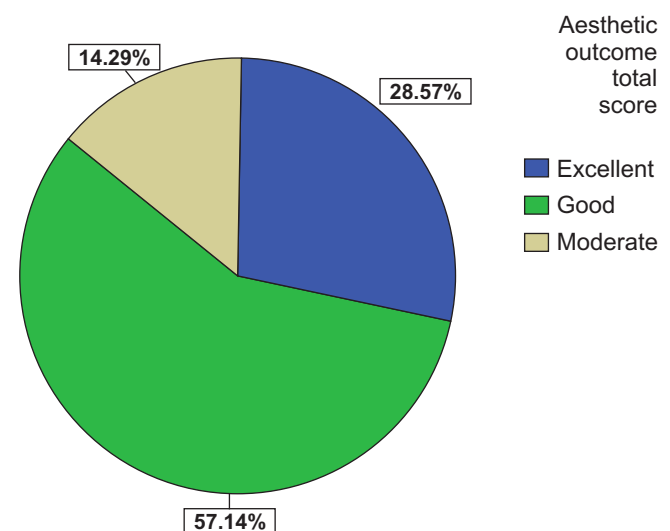


Figure 3: Aesthetic outcome total score

The closing of the donor site was successful via the keystone flap without any major complications. Minor complications were not only insignificant and self-limiting, but they also didn't influence the result. Collectively, these data indicate that, despite a requirement for rather large skin flaps, the ALT donor site closing via the keystone flap is a safe and effective, aesthetically acceptable alternative.

DISCUSSION

Due to this versatility, reliable vascular anatomy, and a very low incidence of donor site morbidity, the ALT flap is recognized as a central part of microsurgical reconstruction. In a low middle income country like Pakistan, the reconstruction procedure is required to

adapt to a series of constraints, including resource limitation and the requirement to find a balance in the restoration and the cosmetic aspect. However, it is hard to achieve ALT donor-site closure in such options. Although split-thickness skin grafting is popular due to its ease of use, it is linked to contour deformity, hypertrophic scarring, color mismatch, and donor-site morbidity that many patients find unsatisfactory. Primarily, the closure may not be achievable when the width of the flap is greater than 8-10 cm, split thickness skin grafting is preferred owing to its simplicity, although many patients remain disgruntled owing to deformity, hypertrophic scars, color match, or donor site morbidity. Our findings clarify that the keystone perforator flap (KPIF), providing tension-free closure, high success rates, minimal complications, and excellent aesthetic outcomes, could be an alternate to the ALT donor site reconstruction.

We have successfully reached the goal of 100% primary closure without serious complications of flap necrosis and compartment syndrome. The KPIF was first described by Behan⁴, who reported excellent perfusion, safety, and highly dependable closure in a variety of anatomical regions. Similar success rates have been reported in four studies that specifically evaluated ALT donor sites. In their series, Kumbla et al.¹⁰ reported 100% donor-site closure, with only 16.7% encountering minor complications like seroma or partial dehiscence. We experienced six Minor complications, such as epidermolysis, partial dehiscence, and hematoma/seroma, in 14.3% of patients in our cohort and they resolved without surgery. These results are consistent with those of Turin et al.,¹¹ who showed that, in comparison to split-thickness skin grafting, keystone closure considerably lowers donor-site morbidity.

Collins and Ayeni's systematic review¹², which summarized ALT donor-site morbidity across various closure techniques, found that wound complications occurred in approximately 5% of cases, seroma in approximately 2-3%, and paresthesia in up to 24% of cases. The higher mean skin paddle width (10.2 cm) in our patient population probably accounts for the slightly higher rates of minor wound-related events. Crucially, lack of significant complications in our study validates the keystone technique's dependability for repairing larger, higher-tension donor-site defects.

In our study, aesthetic results were one of the KPIF's most prominent benefits. Just 14.3% of patients described their outcome as "Moderate," whereas over 85% of patients rated their donor-site appearance as

"Good" or "Excellent." This is in line with research by Dobbs et al.¹³, who used both objective scar scales and patient-reported evaluations to show that keystone flaps had better scar quality and greater patient satisfaction than split-thickness grafts. Clinical photos showing linear scars, harmonious pigmentation, and preserved contour supported the Vancouver Scar Scale (VSS), which offered objective validation of aesthetic results. Grafted donor sites, on the other hand, often result in depressed, irregular scars with color mismatch, which can be upsetting, especially for younger patients or those who have visible donor sites.⁹

There are several ways to close the ALT donor site, and the width of the harvested flap and the properties of the surrounding tissue play a major role in the decision. For flaps narrower than 8 cm, primary closure is preferred but usually safe; beyond this, excessive tension raises the risk of wound breakdown. Split thickness skin grafting is still widely used, but it causes morbidity at a secondary donor site, hypertrophic scarring, and contour compromise. Propeller flaps and KPIF are two tissue-rearrangement techniques that are becoming more and more popular because they provide tension-free closure, maintain thigh contour, and eliminate the need for skin grafts. For intermediate-sized defects (8–12 cm width or 16–30% of thigh circumference), where primary closure is not practical but a graft would be less functional or aesthetically pleasing, modern decision-making algorithms⁹ recommend keystone flaps.

In 42.9% of patients, we found donor-site bulging. The bulging was purely cosmetic and unrelated to functional impairment or patient dissatisfaction, even though this incidence is higher than that reported in some series. As in Type IIA keystone perforator island flaps (KPIF)⁷, which is used in larger defects where deep fascia along the flap is incised and defect is primarily closed without use of skin graft, bulging is frequently associated with fascial release, a technique we employed to improve flap mobility. Purnell et al.¹⁴ and other authors have proposed that postoperative compression, quilting sutures, and careful fascial management can lower the risk of bulging. Although most of our patients were able to tolerate this change in contour, future cases may benefit from improved technique.

Our study's prospective design, standardized three-month follow-up, and use of validated assessment tools (all assessed by a single, qualified assessor to reduce interobserver variability) are among its strong points. A small sample size (n = 28), a brief follow-up period considering that scar maturation and sensory recovery

may take up to a year, and the lack of a comparative group, such as patients undergoing split-thickness graft closure, are some of the limitations. Larger, multicenter designs, longer follow-up periods, and randomized comparisons of closure techniques would be beneficial for future research.

The keystone perforator flap is a safe, dependable, and aesthetically pleasing method for ALT donor-site closure, according to the study's overall findings. The keystone flap offers a reliable and repeatable solution in resource-constrained environments where grafting results might not be ideal, and sophisticated techniques might not be feasible. With the achievement of full closure with little complication and high patient satisfaction, the KPIF provides a clinically valuable method of donor site closure which can be adopted with confidence by reconstructive surgeons working in similar environments.

CONCLUSION

Keystone perforator flap closure allows for the safe, efficient, and aesthetically pleasing management of ALT donor sites. In our series, the approach resulted in dependable closure with low rates of complications, high patient satisfaction, and preserved structural outcomes. These findings support its routine use when

primary closure is not practical, especially in resource-constrained environments where avoiding skin grafts and secondary morbidity is essential.

Conflict of interest: None

Disclaimer: None

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Authors' Contribution

Fatima Sohail: Conception of study / Designing / Planning, Experimentation / Study Conduction, Analysis / Interpretation / Discussion, Manuscript Writing, Critical Review, Facilitated for Reagents / Material Analysis

Ayesha Aslam: Conception of study / Designing / Planning, Experimentation / Study Conduction, Critical Review, Facilitated for Reagents / Material Analysis

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Nousheen Saleem: Analysis / Interpretation / Discussion, Critical Review, Manuscript Writing

Hira Feroz Akbar: Manuscript Writing, Critical Review, Facilitated for Reagents / Material Analysis

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