Article

The Impact of Early and Delayed Fat Transplantation on Scar Quality in Post-Traumatic Reconstruction

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AIM: To evaluate the effects of early versus delayed fat transplantation on post-traumatic scars using adipose-derived stem cells (ADSCs) to enhance scar quality and address the aesthetic and psychological challenges in reconstructive surgery.
METHODS: This retrospective cohort study included 223 patients treated at Capital Medical University Beijing Shijitan Hospital between June 2022 and June 2023. Scar quality was evaluated using the Vancouver Scar Scale (VSS) and scar width measurements at 1, 3, and 4 months postoperatively. Complications were monitored during hospital stays and follow-up visits, while Quality of Life was assessed using the World Health Organization Quality of Life brief version (WHOQOL-BREF).
RESULTS: A retrospective cohort study of 223 patients with post-traumatic scars was conducted to compare the outcomes of early (n = 108) versus delayed (n = 115) fat grafting. Scar width reduction was significantly greater in the early group at 3 months (1.19 $\pm$ 0.30 cm) and 4 months (1.97 $\pm$ 0.58 cm) compared to the delayed group (1.31 $\pm$ 0.34 cm at 3 months and 2.15 $\pm$ 0.55 cm at 4 months; $p < 0.05$). The early group also demonstrated better VSS scores at 3 months (6.35 $\pm$ 1.26) and 4 months (2.16 $\pm$ 0.78) than the delayed group (6.81 $\pm$ 1.48 at 3 months and 2.37 $\pm$ 0.28 at 4 months; $p < 0.05$). However, the early group exhibited a higher complication rate (9.26% vs. 2.61%; p = 0.034). No significant difference was found in Quality of Life scores between the two groups.
CONCLUSIONS: Early fat transplantation improves scar quality but is associated with a higher complication rate.

Keywords: early; delayed; fat transplantation; scar quality; post-traumatic reconstruction

Introduction

Post-traumatic scars pose a significant challenge in reconstructive and aesthetic surgery due to their impact on physical appearance, psychological well-being, and overall Quality of Life [1,2]. These scars can result from various injuries, including surgical procedures, accidents, and other forms of trauma [3]. Current therapeutic strategies focus on improving scar quality by reducing visibility and alleviating symptoms such as itching and stiffness [4]. Among these approaches, fat grafting has emerged as a promising technique for enhancing scar elasticity, contour, and overall appearance [5]. This procedure leverages the regenerative potential of adipose-derived stem cells (ADSCs) within transplanted fat tissue to promote wound healing and improve scar characteristics [6,7]. However, the optimal timing of fat transplantation relative to scar formation remains a subject of ongoing debate.

Traditional scar management practices often favor delayed interventions, based on the assumption that allowing scars to mature sufficiently before modification, thus reducing the risk of complications [8]. However, there is growing interest in early scar management to potentially influence scar proliferation and formation from the outset [9]. Early intervention may present a critical window in which the regenerative and anti-inflammatory properties of ADSCs can be effectively harnessed, potentially leading to improved clinical outcomes [10]. Nevertheless, balancing timely intervention with the risk of complications requires a thorough understanding of the underlying biological processes and patient-specific factors.

The differences between early and delayed fat transplantation are rooted in the distinct pathophysiological characteristics of immature versus mature scar tissue [11]. Early scar sites exhibit heightened cellular activity, including increased fibroblast presence and ongoing collagen deposition, which may respond more effectively to exogenous stimuli such as ADSCs [10]. In contrast, mature scars are typically more fibrotic and exhibit reduced cellular activity, potentially limiting the therapeutic impact of transplanted cells [12].

Although numerous studies have reported the benefits of late-stage fat grafting for scar improvement [13–15], direct comparisons between early and delayed interventions remain scarce. Addressing this knowledge gap is crucial, as early interventions could offer significant advantages in minimizing scar formation and enhancing aesthetic outcomes. However, the decision to pursue early inter-

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vention must be carefully weighed against the increased risk of complications—such as infection and hematoma—associated with active scar remodeling. This retrospective cohort study aims to clarify the effects of early versus delayed fat transplantation on the quality of post-traumatic scars.

Materials and Methods

Case Selection

In this retrospective cohort study, we analyzed 223 patients with post-traumatic scars who were treated at Capital Medical University Beijing Shijitan Hospital between June 2022 and June 2023. The early group (n = 108) consisted of patients who received fat grafting within 4 weeks of the initial trauma, while the delayed group (n = 115) included patients who underwent fat grafting more than 8 weeks after the trauma [16]. Demographic information, including general data, scar width and location, scar scores, and postoperative complications, was collected from the medical records system. The study was approved by the Institutional Review Board and Ethics Committee of Capital Medical University Beijing Shijitan Hospital (Ethical Approval Number: [IIT2024-155-001]), and in accordance with the principles set forth in the Declaration of Helsinki. Informed consent was waived, as the study exclusively utilized de-identified patient data, ensuring no potential harm or impact on patient care. This waiver was granted in compliance with regulatory and ethical guidelines for retrospective research.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Patients aged 18 to 60 years; (2) Patients with presence of one or more post-traumatic scars; (3) Patients with stable mental condition with the ability to cooperate in completing the questionnaire.

Exclusion criteria: (1) Patients with an American Society of Anesthesiologists Physical Status Classification System score greater than II, indicating an increased anesthesia risk; (2) Patients with hypertrophic scars or keloids; (3) Patients with a known history of bleeding disorders, or collagen or elastin disorders; (4) Patients who received scar-related treatment within the past six months; (5) Patients with presence of autoimmune diseases; (6) Patients with mental illness, coagulation disorders, or severe organ damage (e.g., liver or kidney dysfunction); (7) Patients with a predisposition to scarring (scar constitution); (8) Patients who underwent fat grafting between 4 and 8 weeks after the initial trauma were excluded from this study to maintain a clear distinction between the early and delayed groups.

A flowchart illustrating the case selection process is provided in Fig. 1. This diagram outlines the progression from the initial patient pool through various stages of screening and exclusion, culminating in the final cohort used for analysis.

Surgical Methods

All participating board-certified plastic surgeons routinely perform fat transplantation as an integral part of their clinical practice. Surgeries were conducted in accordance with standardized fat transplantation protocols, which adhere to recognized guidelines and best practices [17]. These protocols were rigorously applied throughout the study to ensure consistency in patient care and minimize variability in surgical technique.

Early Transplant Group

The procedure was performed under general intravenous anesthesia with the patient in the supine position. Debridement was carried out as follows:

(a) Thorough cleansing with sterile saline, hydrogen peroxide, and povidone-iodine;

(b) Careful removal of purulent secretions, non-viable tissue, edematous granulation tissue, necrotic periosteum, and cortical bone using a scalpel;

(c) Hemostasis was achieved using monopolar electrocautery;

(d) Final rinsing with sterile saline, hydrogen peroxide, and povidone-iodine, followed by temporary wound coverage with gauze soaked in wound irrigation solution.

Fat Harvesting, Filtration, and Injection

Fat tissue was harvested from the patient's lower abdomen using the Coleman technique. It was then purified and filtered using the gauze method. The filtered fat was injected around and over the wound. The procedure included the following steps:

(a) A tumescent solution, consisting of 10 mL of 2% lidocaine (lidocaine hydrochloride injection; lot number: H20043676, National Pharmaceutical Group Rongsheng Pharmaceutical Co., Ltd., Jiaozuo, China), 0.5 mg of epinephrine (epinephrine bitartrate injection; lot number: H31021177, Shanghai Hefeng Pharmaceutical Co., Ltd., Shanghai, China), 10 mL of 5% sodium bicarbonate (sodium bicarbonate injection; lot number: H51021422, Sichuan Meidakang Huakang Pharmaceutical Co., Ltd., Jinzhu, China), and 500 mL of normal saline (0.9% sodium chloride injection; lot number: H10983064, Jiangxi Kelun Pharmaceutical Co., Ltd., Fuzhou, China) was injected subcutaneously into the designated fat collection area and allowed to infiltrate for 7 minutes;

(b) A 3.0 mm cannula with side holes, attached to a 20 mL syringe to create artificial negative pressure, was used to aspirate the fat from the abdominal subcutis radially;

(c) The 20 mL syringe was then positioned upright for approximately 2 minutes to allow the lower liquid components to separate and be removed, yielding the preliminary purified fat tissue;

(d) The purified fat was spread evenly over layered sterile gauze for approximately 3 minutes to absorb excess tumes-

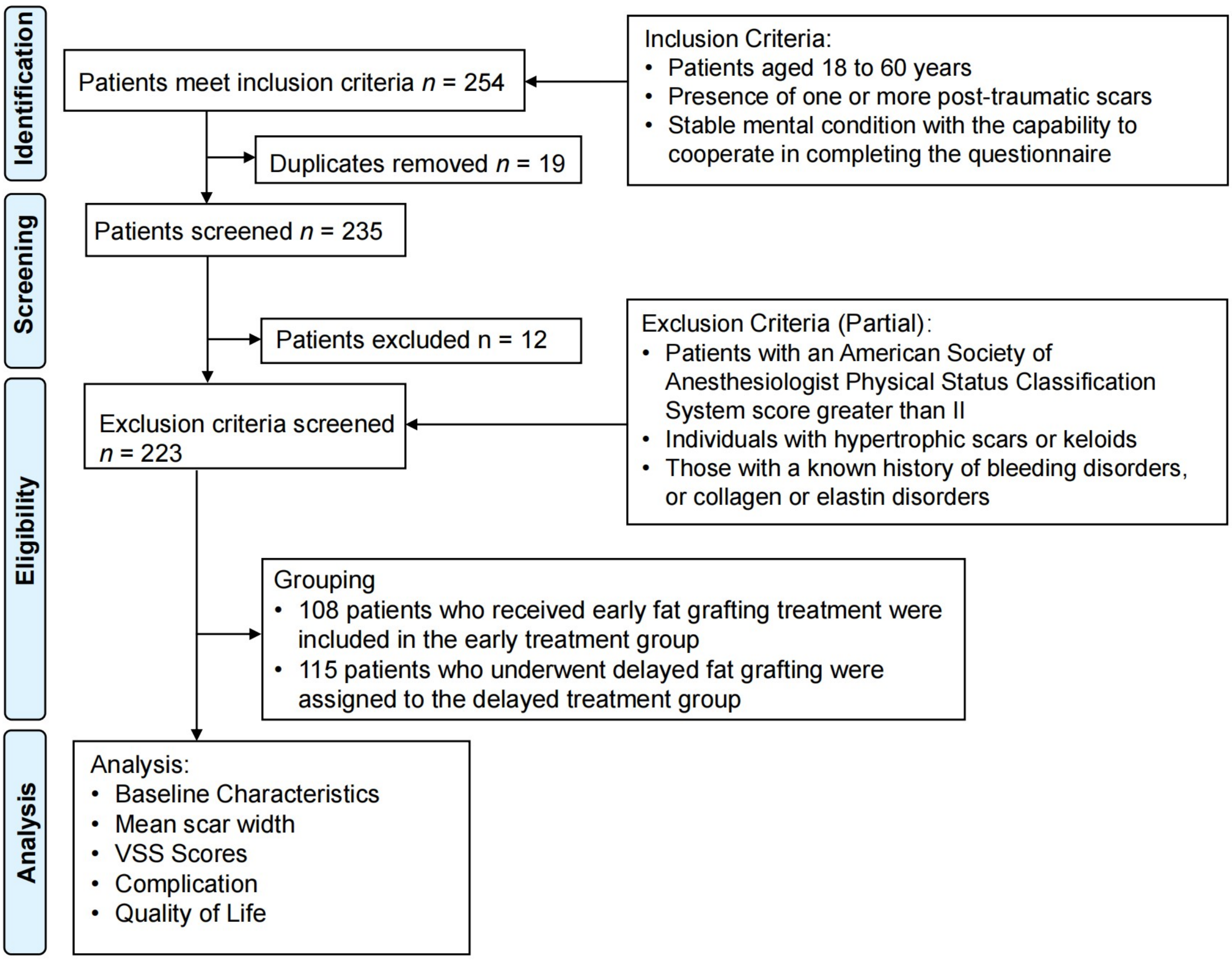

Fig. 1. Flowchart of case selection.

cent solution, tissue fluid, and oil, then collected using a 20 mL syringe for later use;

(e) The fat tissue was transferred to a 2.5 mL screw syringe via a three-way connector, punctured through the skin with a needle, and injected subcutaneously, approximately 1 cm around the wound, using a 1 mm cannula with side holes. A radial multi-tunnel injection technique was employed to avoid excessive skin tension. The remaining fat was evenly spread over the wound surface.

Delayed Transplant Group

Fat was harvested from the patients' abdominal or thigh regions, designated as donor sites. A tumescent anesthesia solution was prepared and injected into the subcutaneous fat layer. Using a 3 mm diameter liposuction cannula attached to a syringe, subcutaneous fat was aspirated in a radial, needle-withdrawal manner to collect the fat tissue. The collected fat tissue was purified using the decanting method. The harvested fat tissue was placed in a sterile centrifuge container and centrifuged for 3 minutes at 3000 rpm. After centrifugation, three layers were formed, with the middle layer being retained for transplantation. The fat was distributed into 1 mL syringes using a 10 mL syringe and injected into the scar tissue through multiple tunnels in a radial, needle-withdrawal manner using a 2 mm blunt needle. This technique was employed to prevent the formation of irregular fat clumps within the scar tissue.

VSS Score

The Vancouver Scar Scale (VSS) [18] is a widely used tool for assessing scars, allowing for the clinical evaluation of four parameters: pliability, height, vascularization, and pigmentation. Scar pliability was assessed by wrinkling a skin fold, while height was measured using a simple rod. Pigmentation and vascularization were evaluated visually. To ensure reliability and consistency, all VSS assessments were conducted by board-certified plastic surgeons with extensive experience in reconstructive surgery. These experts adhered to a rigorous protocol for scoring, which included visual inspection and palpation of the scar tissue. Scoring was performed at 1 month, 3 months, and 4 months post-assessment.

Pliability scores ranged from 0 (normal) to 5 (contracture), with intermediate scores of 1 (supple), 2 (yielding), 3 (firm), and 4 (ropy). Height was categorized as 0 (flat), 1 (less than 2 mm), 2 (2 to 5 mm), and 3 (more than 5 mm). Vascularization was graded from 0 (normal color) to 3 (purple), with intermediate stages of 1 (pink) and 2 (red) [19]. Pigmentation was scored as 0 (normal), 1 (hypopigmentation), 2 (mixed), and 3 (hyperpigmentation). The scale's reliability was confirmed with a Cronbach's alpha of 0.890 [20].

Scar Width

Given that maximum scar spread occurs in the initial months, patients were assessed postoperatively at 1 month, 3 months, and 4 months for scar evaluation. During each visit, an assessor measured the scar width using a digital Vernier caliper with an accuracy of 0.01 mm. Additionally, patients were evaluated for complications, including infection, skin bruising, bleeding, and wound dehiscence.

Complication Monitoring

To comprehensively assess the safety profile of early versus delayed fat transplantation, a rigorous complication monitoring protocol was implemented. All patients were closely observed for potential adverse events during their hospital stay and at follow-up appointments at 1 month, 3 months, and 4 months post-operation. Complications were classified based on their nature and timing relative to the fat transplantation procedure and the stage of wound healing.

Complications were categorized as follows:

1. Procedure-related: These included infections directly attributed to the fat transplantation procedure, such as deep or superficial wound infections occurring within the first few weeks after surgery.

2. Wound-related: These encompassed issues primarily associated with the post-traumatic wound environment, such as skin bruising, bleeding, and wound dehiscence, which could be influenced by the immature state of the scar at the time of intervention.

3. General post-operative: These included complications not directly linked to the fat transplantation but typical of postoperative occurrences, such as minor skin bruising or superficial infections unrelated to the graft site.

The adverse events observed in this study, including infection, skin bruising, bleeding, and wound dehiscence, were evaluated strictly according to relevant standards [21].

Quality of Life Assessment

The World Health Organization Quality of Life brief version (WHOQOL-BREF) was used to evaluate patients' Quality of Life four months after surgery. The WHOQOL-BREF measures four dimensions: psychological well-being, physical health, social relationships, and environmental factors. Higher scores indicate a better Quality of Life, and the tool demonstrated a Cronbach's alpha of 0.9685, confirming its reliability [22].

Data Cleaning and Management

Prior to data analysis, a standardized data cleaning process was conducted to identify and correct inconsistencies, errors, or missing values. This process involved a thorough examination of the dataset, removal of duplicate entries, correction of data entry errors, and imputation of missing values.

Missing values were handled using the Multivariate Imputation by Chained Equations (MICE) method [23] in R Software (4.3.2, R Foundation for Statistical Computing, Vienna, Austria). The process began with basic mean imputation, followed by the construction of a KDTree (R Software, 4.3.2, R Foundation for Statistical Computing, Vienna, Austria) with a complete list of data points. The KDTree was then used to calculate the nearest neighbor (NN) distances. After identifying the K nearest points, their weighted average was taken for imputation.

Statistical Analysis

Data analysis was performed using SPSS statistical software version 29.0 (IBM Corporation, Armonk, NY, USA). Categorical data were represented as [n (%)]. The chi-square test was used for analysis when the sample size was $\geq$40 and the theoretical frequency (T) was $\geq$5. If the sample size was $\geq$40 but $1 \leq T < 5$, a correction formula was applied to the chi-square test. For sample sizes <40 or when $T < 1$, the Fisher's exact test was utilized.

Continuous variables were initially assessed for normal distribution using the Shapiro-Wilk test. For normally distributed data, results were presented as mean $\pm$ standard deviation ($\bar{x} \pm s$). Intergroup comparisons of normally distributed continuous variables were conducted using independent samples *t*-tests to compare means between two groups. A significance level of $p < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

The early group had a mean age of 23.91 $\pm$ 2.49 years, compared to 24.36 $\pm$ 1.94 years in the delayed group (t = 1.489, p = 0.138) (Table 1). Gender distribution was nearly identical between groups, with 66.67% male in the early group and 66.09% in the delayed group (χ^2 = 0.008, p = 0.927). Participants' body mass index was similar between groups (t = 0.270, p = 0.787). A history of smoking was reported in 33.33% of the early group and 33.91% of the delayed group (χ^2 = 0.008, p = 0.927), while drinking history was also comparable (25.93% vs 26.09%; χ^2 = 0.001, p = 0.978). Employment status, as well as the prevalence of hypertension and diabetes, showed no significant differences between the groups. Education level variances were not statistically significant (χ^2 = 0.891, p = 0.640), and initial scar width was slightly smaller in the early group (6.93 $\pm$ 1.21 cm) compared to the delayed group (7.24 $\pm$ 1.52

Table 1. Baseline characteristics of participants.

Parameters	Early group (n = 108)	Delayed group (n = 115)	t/χ^2	p
Age (years)	23.91 ± 2.49	24.36 ± 1.94	1.489	0.138
Gender (Male/Female)	72/36	76/39	0.008	0.927
Body mass index (kg/m^2)	24.11 ± 4.35	24.26 ± 4.12	0.270	0.787
Smoking history [n (%)]	36 (33.33%)	39 (33.91%)	0.008	0.927
Drinking history [n (%)]	28 (25.93%)	30 (26.09%)	0.001	0.978
Employment [n (%)]	82 (75.93%)	87 (75.65%)	0.002	0.962
Hypertension [n (%)]	2 (1.85%)	1 (0.87%)	0.003	0.956
Diabetes [n (%)]	1 (0.93%)	3 (2.61%)	0.195	0.659
Degree of education			0.891	0.640
-Junior high school and below	11 (10.19%)	16 (13.91%)		
-High school	36 (33.33%)	34 (29.57%)		
-College diploma or above	61 (56.48%)	65 (56.52%)		
Scar width (cm)	6.93 ± 1.21	7.24 ± 1.52	1.683	0.094
Location of trauma [n (%)]			2.542	0.468
-Abdomen	43 (39.81%)	50 (43.48%)		
-Lower limb	15 (13.89%)	19 (16.52%)		
-Upper limb	24 (22.22%)	28 (24.35%)		
-Face	26 (24.07%)	18 (15.65%)		

Table 2. Comparison of scar width between the two patient groups.

Parameters		Early group (n = 108)	Delayed group (n = 115)	t	p
Scar width (cm)	1 month	0.68 ± 0.11	0.69 ± 0.17	0.250	0.803
	3 months	1.19 ± 0.30	1.31 ± 0.34	2.766	0.006
	4 months	1.97 ± 0.58	2.15 ± 0.55	2.411	0.017

cm), though this difference was not statistically significant (t = 1.683, p = 0.094). The location of trauma was also similar between the groups (χ^2 = 2.542, p = 0.468). These results indicate that the baseline characteristics of the participants were well-balanced across groups, providing a robust basis for the comparative analysis of scar quality outcomes following fat transplantation.

Mean Scar Width

At 1 month, the scar width was similar between the early group and the delayed group (0.68 ± 0.11 cm versus 0.69 ± 0.17 cm, t = 0.250, p = 0.803) (Table 2). However, at 3 months, the early group demonstrated a significantly smaller scar width (1.19 ± 0.30 cm) compared to the delayed group (1.31 ± 0.34 cm), with statistical significance (t = 2.766, p = 0.006). This trend continued at 4 months, where the early group maintained a narrower scar width (1.97 ± 0.58 cm) than the delayed group (2.15 ± 0.55 cm), again showing a significant difference (t = 2.411, p = 0.017). These results suggest that early fat transplantation may contribute to improved scar quality in the months following post-traumatic reconstruction.

VSS Scores

At 1 month, the VSS scores were similar for the early group and the delayed group (9.48 ± 2.79 versus 9.55 ± 2.64, t = 0.203, p = 0.839) (Table 3). At 3 months, however, the early group showed a significantly lower mean VSS score of 6.35 ± 1.26 compared to 6.81 ± 1.48 in the delayed group (t = 2.461, p = 0.015). This improvement in scar quality was further supported by data at 4 months, where the early group had a significantly lower VSS score (2.16 ± 0.78) than the delayed group (2.37 ± 0.28) (t = 2.666, p = 0.009). These findings suggest that early fat transplantation may enhance scar quality more effectively than delayed intervention in post-traumatic reconstruction.

Complication

In the early group, 4 patients had infections, 1 patient had skin bruising, 3 patients had bleeding, and 2 patients had wound dehiscence (Table 4). The delayed group experienced infection in 1 patient, skin bruising in 1 patient, and wound dehiscence in 1 patient. The overall incidence rate of complications was significantly higher in the early group, with 10 complications (9.26%) compared to 3 (2.61%) in the delayed group (χ^2 = 4.487, p = 0.034). These results suggest that early fat transplantation may be associated with a higher complication rate compared to delayed intervention.

Quality of Life

For psychological health, the early group scored 16.11 ± 2.65, while the delayed group scored 16.63 ± 4.36 (t = 1.077, p = 0.283) (Table 5). Physiologically, the early group's mean score was 17.16 ± 2.81 compared to 17.25 ± 2.62 in the delayed group (t = 0.256, p = 0.798). So-

Table 3. VSS scores between the two patient groups.

Parameters		Early group (n = 108)	Delayed group (n = 115)	t	p
VSS scores	1 month	9.48 ± 2.79	9.55 ± 2.64	0.203	0.839
	3 months	6.35 ± 1.26	6.81 ± 1.48	2.461	0.015
	4 months	2.16 ± 0.78	2.37 ± 0.28	2.666	0.009

VSS, Vancouver Scar Scale.

Table 4. Comparison of complication rates between the two patient groups.

Parameters	Early group (n = 108)	Delayed group (n = 115)	χ^2	p
Infection (n)	4	1		
Skin bruising (n)	1	1		
Bleeding (n)	3	0		
Wound dehiscence (n)	2	1		
Incidence rate [n (%)]	10	3	4.487	0.034

cial relations scores were also similar, with the early group scoring 17.17 ± 3.25 and the delayed group 17.36 ± 1.63 (t = 0.521, p = 0.603). Regarding environmental factors, the early group had a mean score of 17.32 ± 3.07, slightly lower than the delayed group's (18.14 ± 3.65), though this difference was not statistically significant (t = 1.810, p = 0.072). Overall, these results indicate that there were no significant disparities in Quality of Life between the groups at four months following post-traumatic reconstruction.

Discussion

In this study, we explored the differential effects of early versus delayed fat transplantation on the quality of scars resulting from post-traumatic reconstruction.

The enhanced scar quality observed in the early fat transplantation group can be attributed to several potential mechanisms. Primarily, ADSCs present in the transplanted fat tissue are known to promote angiogenesis, fibroblast proliferation, and collagen remodeling—all of which are crucial for effective wound healing and scar formation [24,25]. Early fat grafting introduces these cells into the wound milieu when the scar is still nascent and metabolically active, potentially allowing ADSCs to exert their regenerative functions more effectively [26]. This may explain the reduced scar width and improved VSS scores observed in the early treatment group.

Regarding the observed increase in scar width over time, it is essential to consider the dynamic nature of scar maturation. Initially, scars tend to exhibit swelling and widening as part of the inflammatory and proliferative phases of wound healing. During these phases, new blood vessels form, and granulation tissue develops, causing temporary expansion. Over time, scars typically undergo contraction and remodeling; however, this process may not become apparent until the first few months post-surgery [27]. Therefore, the increasing scar width noted in our study likely reflects the natural progression of scar evolution rather than a failure of the treatment.

Another factor contributing to improved scar outcomes was the biomechanical environment created by the early intervention. The deposition of fat serves as a cushion that can disperse mechanical stress along the scar, minimizing tension and thereby reducing excessive scar formation [28,29]. This mechanical load redistribution might be less effective if the grafting was delayed, as the scar tissue and surrounding skin have already undergone considerable remodeling by that time [30].

In addition, the delayed transplantation group's less favorable scar metrics could be due to the physiological state of the scar at the time of intervention. By then, scars were often stiffer and more mature, exhibiting a reduced response to regenerative signals provided by the transplanted fat [30]. This aligns with the notion that the latter stages of scar formation are characterized by collagen that is less amenable to remodeling, thereby diminishing the therapeutic impact of fat grafting [7,31].

Despite the superior scar quality observed in the early transplantation group, this study noted a higher complication rate, predominantly infections and bleeding. One mechanism that may underlie this increased complication rate is the heightened inflammatory response induced by surgical intervention in the context of an immature scar. Early fat transplantation interrupts the natural wound healing cascade, potentially leading to an exaggerated inflammatory response, which might predispose the patient to complications such as infection or bleeding. The wound bed at one month may still contain actively remodeling tissues that are susceptible to disruption, augmenting the risk for surgical trauma-related complications [32,33].

Furthermore, the local immune environment during early transplantation could be less conducive to tolerating surgical interventions. The introduction of exogenous material into a metabolically active scar may provoke an unintended

Table 5. Comparison of Quality of Life at four months post-operation between the two patient groups.

Parameters	Early group (n = 108)	Delayed group (n = 115)	*t*	*p*
Psychology	16.11 ± 2.65	16.63 ± 4.36	1.077	0.283
Physiology	17.16 ± 2.81	17.25 ± 2.62	0.256	0.798
Social relations	17.17 ± 3.25	17.36 ± 1.63	0.521	0.603
Environment	17.32 ± 3.07	18.14 ± 3.65	1.810	0.072

immune response, potentially accounting for the increased complications noted in this study. In contrast, delayed intervention occurs when the immune milieu has stabilized, possibly leading to a more subdued response to grafting, as suggested by lower complication rates.

Interestingly, despite the variations in scar quality and complications, our findings indicate no significant difference in the Quality of Life scores between the two groups. This suggests that while the physical characteristics of the scar improve with early intervention, it does not necessarily correlate directly with the patient's perceived well-being. One possible mechanism for this dissociation is that patients may adapt to their scars over time, leading to a stabilization of psychological impact regardless of the scar's objective appearance [9,10,34]. Additionally, the presence of complications in the early group could negatively influence patients' perceptions, offsetting any positive effects from improved scar aesthetics. This complex interplay underscores the importance of considering both clinical outcomes and subjective measures when evaluating treatment efficacy. It also highlights the need to incorporate patient education and counseling into the treatment strategy, especially in planning early intervention, to manage patient expectations regarding potential complications. By setting realistic expectations and providing comprehensive support, healthcare providers can better align clinical goals with patient satisfaction, ultimately enhancing overall treatment outcomes.

To contextualize our findings within the existing literature, it is important to compare them with previous studies on early versus delayed fat transplantation in post-traumatic reconstruction. While there are limited studies directly comparing these two approaches, several investigations have examined the timing of fat grafting in various reconstructive scenarios. For instance, a study by Ahmad *et al*. [35] found that early fat grafting in burn patients led to improved tissue regeneration and reduced scar contracture, which aligns with our observations of enhanced scar quality in the early transplantation group. Conversely, research conducted by Hanson [36] suggested that delayed fat transplantation might offer advantages in terms of lower complication rates, echoing our finding of increased complications associated with early intervention. Moreover, a systematic review by Kenny *et al*. [37] highlighted the variability in outcomes depending on the anatomical site of trauma and the extent of initial injury. This variability underscores the importance of individualized treatment planning based on patient-specific factors. Our study adds to this body of knowledge by providing evidence that while early fat transplantation can lead to better scar quality, it must be balanced against the risk of higher complication rates. Future research should aim to identify predictive factors for the optimal timing of fat transplantation, taking into account both biological mechanisms and patient characteristics.

This study's findings, while informative, should be considered within the context of certain limitations. The retrospective nature of the study inherently limits its ability to control for selection bias and all potential confounding variables, which may affect the reliability of the observed associations between treatment timing and scar outcomes, as well as impact the generalizability and interpretation of the results. The reliance on de-identified data further restricts the capture of all relevant clinical characteristics, such as detailed comorbidities or medication use that could influence healing outcomes. Additionally, while the VSS is a well-established tool for evaluating scar quality, it is inherently subjective. In addition to VSS scoring being performed by certified experts to ensure accuracy, the inclusion of objective measures such as 3D imaging to quantify scar volume or texture would have strengthened our methodology. The follow-up period, while adequate for observing initial scar changes, may not capture the long-term effects of fat transplantation on scar maturation and patient satisfaction. Variations in surgical technique and the subjective nature of VSS scoring could introduce variability, highlighting the need for standardization in the assessment process.

Moreover, the lack of significant differences in Quality of Life scores may also be influenced by factors not captured in this study, such as the level of psychological support received, the presence of pre-existing scars, and patients' expectations regarding the outcomes of the procedure. These psychosocial elements can significantly shape patients' perceptions and overall satisfaction with their recovery and appearance. Future studies addressing these limitations, as well as employing standardized surgical techniques across different time frames, could provide more robust evidence and enhance the understanding and application of fat transplantation in clinical practice.

Conclusions

In conclusion, our study has elucidated key distinctions between early and delayed fat transplantation, highlighting both the potential benefits and drawbacks of early intervention in terms of scar quality and complication rates. The findings advocate for a more nuanced approach to post-traumatic scar management, weighing the benefits of improved scar appearance against the heightened risk of early postoperative complications. Advancements in cellular and molecular understanding of fat transplantation in a wound milieu hold promise for tailoring interventions to balance these outcomes and ultimately improve patient satisfaction and Quality of Life in reconstructive surgery.

Availability of Data and Materials

The datasets used during the present study are available from the corresponding author upon reasonable request.

Author Contributions

JL, CL and YFH: Conceptualization. JL, YGS and YFH: Writing-Original Draft. TS, CY and HYY: Data Curation. YGS, JL and YFH: Formal analysis. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board and Ethics Committee of Capital Medical University Beijing Shijitan Hospital (Ethical Approval Number: [IIT2024-155-001]), and in compliance with the principles outlined in the Declaration of Helsinki. Informed consent was waived because the study exclusively utilized de-identified patient data, ensuring no potential harm or impact on patient care. This waiver was granted in compliance with regulatory and ethical guidelines for retrospective research.

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Conflict of Interest

The authors declare no conflict of interest.

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