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Review

Donor site healing in follicular unit extraction hair transplantation: current evidence, cellular mechanisms, and future research directions

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Abstract

Follicular unit extraction (FUE) has become a leading technique in hair transplantation, yet optimal management of the donor area remains a clinical challenge. This systematic review analyzes intraoperative and postoperative interventions applied to the donor area in FUE hair transplantation, with a focus on both clinical outcomes and the cellular and molecular mechanisms involved in tissue repair, inflammatory response, and regenerative processes. A comprehensive literature search was conducted in PubMed and EMBASE (January 2000–June 2025), identifying clinical studies that evaluated donor area treatments and reported outcomes related to healing, inflammation, infection, and patient satisfaction. Four studies met the inclusion criteria, encompassing corticosteroid infiltration, platelet-rich plasma (PRP), timing of postoperative care, and hair follicle-derived microtissue (HFMT) application. Evidence suggests that intraoperative corticosteroid use significantly reduces postoperative edema, likely by modulating local inflammatory pathways and vascular permeability. Early postoperative wound care is associated with decreased folliculitis incidence, highlighting the importance of timely intervention in preventing microbial colonization and dysregulated immune responses. While PRP and HFMT show potential for enhancing cellular proliferation and accelerating wound closure, current data are limited by heterogeneity in study design and lack of standardized molecular endpoints. The review identifies a critical gap in mechanistic studies exploring the cellular dynamics of donor area healing, including the roles of keratinocytes, fibroblasts, and immune cells. Future research integrating molecular biomarkers and advanced imaging is needed to elucidate the pathways driving optimal tissue regeneration. These insights may inform evidence-based protocols that not only improve clinical outcomes but also advance our understanding of scalp wound biology in the context of FUE.

Keywords: Hair transplantation, FUE, Donor area, HFMT, PRP, Corticosteroids, Complications, Healing, Postoperative pain.

1. Introduction

The follicular unit extraction (FUE) technique has revolutionized the field of hair transplantation, becoming one of the most widely used surgical options for the treatment of androgenic and other types of alopecia. FUE offers multiple advantages, including less visible scarring, reduced postoperative pain, and faster recovery, which has contributed to its increasing popularity among patients and surgeons [1–3].

Despite technical advancements, the donor area continues to represent a significant clinical challenge. This region, from which follicular units are harvested, is a limited resource whose integrity is essential to avoid aesthetic complications such as a "mottled" appearance or visible scarring, and to preserve the possibility of future procedures [1, 4, 5]. Proper management of the donor site not only influences immediate outcomes in terms of healing and pain but also impacts the potential for future transplants and the patient's overall perception of the procedure [6, 7].

Several strategies have been proposed to optimize donor area recovery and prevent postoperative complications. Among the most widely used are intraoperative corticosteroid infiltration, specific dressings, topical antibiotic or antiseptic solutions, platelet-rich plasma (PRP) therapy, and emerging techniques such as hair follicle-derived microtissue (HFMT) [8–11]. However, scientific evidence supporting these interventions remains limited, heterogeneous, and fragmented.

Studies like Fattah et al. have shown that adding triamcinolone to the local anesthetic solution can significantly reduce postoperative edema and improve patient satisfaction, lowering edema incidence from 40% to 9% [8]. Additionally, Zhou et al.'s multicenter retrospective study found that initiating postoperative care later than 72 hours after surgery is associated with a higher incidence of folliculitis in the donor area—a common complication that can compromise both aesthetic and functional results [9].

Guo et al. published a randomized clinical trial evaluating HFMT—an emulsion obtained from perifollicular

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tissue collected during surgery, which may accelerate wound healing and reduce early postoperative pain and pruritus. However, the study has methodological limitations, including potential bias due to its split-scalp design and monocentric setting. Other studies have explored the role of PRP as a regenerative therapy in the postoperative period, but results have been inconsistent, often showing no clinically significant differences compared to controls [10, 12].

Most studies focus on the recipient area or overall transplant outcomes, and there is a lack of literature specifically addressing interventions in the donor area, their clinical efficacy, and their impact on recovery [13, 14]. This gap justifies the need for a systematic review dedicated to this critical region, with the goal of guiding clinical decisions based on the best available evidence.

This systematic review analyzes intraoperative and postoperative treatments described in the scientific literature regarding the donor area after FUE hair transplantation. It explores their impact on clinical recovery, complication prevention, patient satisfaction, and aesthetic improvement. Additionally, knowledge gaps are identified, and research priorities are outlined for future investigations.

2. Materials and Methods

A systematic review was conducted in accordance with the PRISMA 2020 guidelines to evaluate treatments applied to the donor area in patients undergoing follicular unit extraction (FUE) hair transplantation. The review protocol was prospectively designed by the authors, ensuring methodological rigor, transparency, and reproducibility, although it was not registered in PROSPERO. The research question was framed using the PICO model: the population included patients receiving FUE hair transplantation (P: Population); interventions comprised intraoperative and postoperative treatments targeting the donor site, such as corticosteroid infiltration, specialized surgical techniques, wound care, antiseptics, hair follicle microtransplantation (HFMT), and platelet-rich plasma (PRP) (I: Intervention); comparisons involved no treatment, placebo, or alternative postoperative protocols (C: Comparison); and outcomes focused on donor area recovery parameters including pain (measured by VAS), pruritus, erythema, infection, edema, folliculitis, necrosis, healing quality (assessed by POSAS), patient satisfaction, and overall recovery time (O: Outcomes).

2.1. Search strategy

A comprehensive literature search was performed in the PubMed (MEDLINE) and EMBASE databases to maximize sensitivity. Search terms combined controlled vocabulary (MeSH) and keywords related to hair transplantation and donor site management, including “Hair Transplantation,” “follicular unit extraction,” “postoperative care,” “wound healing,” “donor area,” and specific interventions such as “topical corticosteroids,” “platelet-rich plasma (PRP),” “low-level laser therapy,” and “hydrocolloid dressings.” Boolean operators (AND/OR) were used to refine the search strategy. Filters limited results to publications from January 2000 through June 2025, and eligible study designs included clinical trials, observational studies, and case series. To ensure comprehensiveness, reference lists of relevant articles were manually screened for additional studies. The search process adhered to PRISMA 2020 recommendations to ensure transparency and reproducibility.

2.2. Inclusion criteria

Studies were included if they involved adult patients undergoing FUE hair transplantation and evaluated intraoperative or postoperative interventions specifically targeting the donor area. Eligible studies reported quantitative or qualitative clinical outcomes related to donor site recovery, such as pain, inflammation, folliculitis, necrosis, healing, and patient satisfaction. Study designs considered for inclusion comprised randomized clinical trials, cohort studies, case-control studies, and case reports.

2.3. Exclusion criteria

Studies were excluded if they focused exclusively on the recipient area or evaluated only the follicular unit transplantation (FUT) technique. Narrative reviews, editorials, letters to the editor, and expert opinions lacking original clinical data were also excluded. Additionally, studies that did not report specific clinical outcomes related to the donor area were omitted.

2.4. Data extraction

Data extraction was performed using a Microsoft Excel spreadsheet, capturing bibliographic details (author, year, country), study design and sample size, characteristics of donor area interventions, comparators, clinical outcomes, follow-up duration, assessment scales, and main conclusions. Methodological quality of randomized controlled trials was assessed using the Cochrane Risk of Bias 2.0 (RoB 2) tool, which evaluates domains including randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. Observational studies were appraised with the Newcastle-Ottawa Scale (NOS), focusing on selection, comparability, and outcome/exposure domains.

2.5. Statistical analysis

Due to the limited number and heterogeneity of the included studies, a quantitative meta-analysis was not feasible. Instead, a descriptive synthesis of the available data was performed. For randomized controlled trials and observational studies, reported p-values, odds ratios (OR), and 95% confidence intervals (CI) were extracted directly from the original publications. For continuous variables such as pain and pruritus (measured by Visual Analog Scale), means and standard deviations were recorded when available. For categorical outcomes, such as incidence of edema or folliculitis, proportions and risk estimates were summarized.

Where possible, effect sizes were compared across studies to evaluate the relative efficacy of interventions. Statistical significance was defined as $p < 0.05$. The methodological quality and risk of bias of the included studies were assessed using the Cochrane RoB 2.0 tool for randomized trials and the Newcastle-Ottawa Scale (NOS) for observational studies. No imputation of missing data was performed, and all analyses were based on reported outcomes. Due to the diversity in study design, intervention protocols, and outcome measures, results are presented narratively and in tabular form to facilitate comparison.

3. Results

The database search initially identified a total of 7 records. Ultimately, 4 studies met the inclusion criteria and were included in this systematic review. The selected studies comprised one randomized controlled trial (Guo et al., 2024 [11]), two observational studies (Fattah, 2022 [8]); Zhou et al., 2023 [9]), and one case report (Karaçal et al., 2012 [15]) (Table 1).

The randomized controlled trial by Guo et al. (HFMT for the donor area) compared the use of HFMT with topical mupirocin and no treatment in the donor area after FUE. It was a split-scalp study in which each patient served as their own control. The study population included 98 patients (mean age not specified), with one group treated with HFMT vs. mupirocin and another group with HFMT vs. no treatment. On day 3, the wound closure rate was significantly higher in the sites treated with HFMT ($p < 0.01$). Pain (measured by the Visual Analog Scale: VAS) was significantly lower on days 3, 5, and 7 for HFMT compared to both control groups. A similar reduction in pruritus was observed with HFMT. Limitations included lack of long-term follow-up, single-center design, no double-blinding, and non-standardized wound healing assessment [11].

The prospective observational study conducted by Fattah (Triamcinolone + PRP), with a sample of 271 patients with androgenetic alopecia, compared the effects of triamcinolone and PRP applied in combination with historical controls without treatment. Triamcinolone 40 mg was added to the local anesthetic, and PRP sessions were performed at months 2, 4, and 6 post-FUE. Results showed a reduction in postoperative edema from 40% to 9% ($p < 0.001$) after triamcinolone introduction, and an increase in the percentage of highly satisfied patients from 64.5% to 83.7% with additional PRP use. In this study, there was no parallel control group; PRP results were perception-based, with no objective wound healing scales or blinded evaluation [8].

Zhou et al. (Postoperative care and folliculitis) conducted a multicenter retrospective study analyzing 1317 patients after FUE transplantation in 4 centers in China, focusing on factors associated with folliculitis. A 12.1% global incidence of folliculitis was observed, with a higher risk if the first wound care was performed after 3 days (OR 1.55; 95% CI 1.08–2.22). Other associated risk factors included seasonality (summer), sessions exceeding 4000 follicular units (FUs), and implantation densities above 45 FUs/cm². This study's limitations included its retrospective design, lack of validated clinical scales, and self-reported data [9].

Finally, the case report of severe occipital region necrosis after FUE, presented by Karaçal et al. (Donor area necrosis), identified inadequate postoperative care and possible local vascular compression as the main causes. Although it is a single case and thus very low-level evidence, it is clinically relevant as a warning and supports the findings by Zhou et al. regarding donor area wound care [15].

The methodological quality assessment of the included studies showed considerable variability. The only randomized controlled trial (Guo et al.) was evaluated using the Cochrane RoB 2.0 tool, obtaining a rating of "some concerns" due to limitations in blinding and lack of prospective protocol registration. The observational studies were assessed with the Newcastle-Ottawa Scale (NOS), with Zhou et al. scoring 8 out of 9 points (high quality), while the study by Fattah scored moderately (6/9), mainly due to lack of multivariate adjustment and absence of prolonged follow-up. Finally, the case report by Karaçal et al. was not assessable with these tools and was considered as very low-quality evidence due to its anecdotal nature and lack of generalizability.

4. Discussion

The management of the donor area in FUE hair transplantation is a critical component to preserve the aesthetic integrity of the occipital region, reduce postoperative complications, enable future hair restoration sessions if needed, and enhance overall patient experience [1, 3, 11]. Despite significant advancements in surgical precision and automation of follicular extraction, adjunctive donor site treatments remain under-standardized and poorly evaluated in the scientific literature. This systematic review critically analyzes the available evidence on intraoperative and postoperative interventions specifically applied to the donor area, extracting clinically relevant conclusions and highlighting gaps where further research is urgently needed.

Among all interventions reviewed, the intraoperative use of corticosteroids—specifically the addition of triamcinolone to the local anesthetic—emerged as the most promising in terms of clinical efficacy and feasibility. Fattah's prospective observational study reported a remark-

Table 1. Summary of included studies evaluating donor area interventions after FUE hair transplantation.

Author (Year)	Study Design	Sample Size (n)	Donor Area Intervention	Comparator / Control	Outcomes Evaluated	Follow-up Duration
Guo et al. (2024)	Randomized controlled (split-scalp)	98	Topical HFMT	Mupirocin / no treatment	Wound closure rate, pain (VAS), pruritus (VAS)	Days 3, 5, 7
Fattah (2021)	Prospective observational	271	Triamcinolone + PRP	No intervention	Edema, patient satisfaction, gene expression	12 months
Zhou et al. (2023)	Multicenter retrospective	1317	Early vs. delayed first dressing	≤3 days vs. >3 days	Incidence of folliculitis, multivariate analysis	9 months
Karaçal et al. (2011)	Case report	1	No treatment	—	Necrosis, secondary wound healing	6 months

Where, HFMT: Hair follicle-derived microtissue; PRP: Platelet-rich plasma; VAS: Visual Analog Scale

able reduction in postoperative edema, from 40% to 9%, after incorporating triamcinolone into the anesthetic solution [8]. This finding is highly relevant, as edema can prolong postoperative discomfort, impair quality of life, and potentially increase the risk of secondary infections [9, 13, 16–18].

While the study's limitations include the absence of a parallel control group and lack of validated edema scales, its substantial sample size (271 patients) and the magnitude of the observed effect confer meaningful clinical value. Corticosteroids are inexpensive, widely available drugs, and their integration into standard protocols is viable, provided that adverse effects are monitored. Given their anti-inflammatory profile and impact on vascular permeability, triamcinolone may also contribute to improved early wound healing, although this was not directly assessed in the study [19–22].

The second most relevant finding stems from the multicenter study by Zhou et al. [9], which demonstrated that delaying the first postoperative dressing beyond 72 hours was associated with a significantly higher incidence of donor site folliculitis (OR: 1.55; 95% CI 1.08–2.22). This study, which included 1,317 patients, provides robust evidence regarding the preventive value of early and appropriate postoperative care.

This underscores an often-overlooked dimension: the importance of immediate postoperative follow-up, the quality of which may vary by clinic, practitioner, or even season (summer was also associated with higher infection rates in this study). Unlike other less common complications, folliculitis has a notable prevalence—affecting 12.1% of patients in this cohort—and can compromise both aesthetic outcomes and patient adherence to treatment.

Early wound care should be considered a foundational element of the postoperative protocol, including cleansing, hydration, and prevention of follicular occlusion. Clinics that apply generalized recommendations without adapting follow-up to individual clinical variables may be exposing patients to unnecessary risks. In this regard, in-person follow-up becomes critical after FUE procedures [2, 3, 13, 14].

The case report by Karaçal et al. [15], although low in evidence level, serves as a cautionary tale due to its severity. The appearance of extensive necrosis in the donor area due to lack of postoperative care reinforces the notion that, beyond active treatments, the omission of structured clinical follow-up constitutes a serious risk factor. While such extreme cases are rare, their occurrence demands clear and systematic guidelines for all patients undergoing FUE.

In contrast, treatments such as HFMT and PRP, while promising, currently lack the robust evidence needed for widespread clinical adoption.

The study by Guo et al. on topical use of hair follicle-derived microtissue (HFMT) stands out for its controlled design but exhibits several limitations. Although wound closure and reductions in pain/pruritus were superior to mupirocin or no treatment, the study was monocentric, used non-validated healing scales, lacked follow-up beyond 7 days, and did not clarify the bioactive composition of HFMT. Adverse effects and tolerance were also not addressed. Furthermore, the comparison with mupirocin is debatable, as this antibiotic is not a universal standard for FUE postoperative care. HFMT remains a promising research avenue, but is not yet supported for clinical use outside of controlled studies.

Similarly, although PRP has been advocated in the literature for its ability to modulate inflammation and stimulate growth factors, its direct application to the donor site remains underexplored, and its benefits appear limited. Fattah included PRP in the postoperative regimen and reported improved patient satisfaction, but objective donor site outcomes such as healing, recovery time, or complication rates were not evaluated. The study design also does not allow isolation of PRP's effect from that of triamcinolone.

Other studies, such as those by Elariny et al. [10] and Sabanciogullarindan et al. [23], have used PRP in scar restoration settings, but their results focused on recipient areas or specific populations, making them not directly translatable to FUE donor site management.

A major limitation across all included studies is the lack of standardization in outcome reporting. The use of different scales—or no scales at all—combined with variable follow-up and heterogeneous protocols, impedes systematic comparison of results and precludes meta-analytical synthesis. Validated tools such as POSAS or Vancouver Scale should be routinely integrated into future research.

There is an urgent need for multicenter randomized controlled trials with well-defined protocols, mid-term follow-up, and patient-centered outcomes—including wound healing, erythema, edema, pruritus, pain (particularly nocturnal pain that interferes with rest during the initial nights after hair transplantation), desquamation, infection, and patient satisfaction. Only high-quality evidence will enable the development of practical guidelines to optimize donor site care in FUE hair transplantation procedures.

5. Conclusions

The management of the donor area in FUE hair transplantation remains a pivotal aspect for improving both clinical and aesthetic outcomes. This systematic review suggests that intraoperative corticosteroid use, particularly triamcinolone added to local anesthesia, may significantly reduce postoperative edema and thus improve immediate recovery. Likewise, initiating postoperative wound care within the first 72 hours is associated with a lower incidence of folliculitis, reinforcing the need for standardized protocols and early patient follow-up.

In contrast, emerging therapies such as hair follicle-derived microtissue (HFMT) and platelet-rich plasma (PRP), while showing preliminary promise, currently lack sufficient methodological rigor to support widespread clinical adoption. HFMT, in particular, requires further multicenter trials, standardization of its preparation, and mid-term outcome evaluations. PRP must demonstrate objective improvements beyond subjective patient satisfaction, especially in terms of wound healing and complication prevention.

In summary, optimizing donor site management in FUE hair transplantation remains a clinically relevant challenge, often underestimated, yet crucial to the overall success of the procedure and patient perception. We recommend prioritizing interventions supported by stronger levels of evidence, particularly intraoperative corticosteroid use and early postoperative wound care, due to their demonstrated impact on reducing edema, preventing complications, and improving early recovery outcomes. It is

also essential to advance the development and implementation of robust, randomized, multicenter clinical trials that enable objective, reproducible, and patient-centered comparisons across different treatment modalities. Key outcome measures should include wound healing, quality of life, and aesthetic functionality. To deepen our understanding of the mechanisms governing tissue regeneration in the donor area, future research must incorporate molecular biomarkers and advanced imaging technologies. These tools will allow for a more precise characterization of the cellular and immunological processes involved, thereby supporting the development of personalized, evidence-based therapeutic protocols that improve both clinical efficacy and patient outcomes.

Conflict of interests
The authors have no conflicts with any step of the article preparation.

Consent for publications
The author read and approved the final manuscript for publication.

Ethics approval and consent to participate
No human or animals were used in the present research.

Informed consent
The authors declare that no patients were enrolled in this study.

Availability of data and material
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' contributions
Ney Arencibia Pérez and María José Guerrero Roldán both contributed substantially to the conception and design of the study, data acquisition, and interpretation of results. Ney Arencibia Pérez drafted the manuscript and coordinated the systematic review process. María José Guerrero Roldán provided critical revisions and contributed to the final approval of the version to be published. Both authors agree to be accountable for all aspects of the work.

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