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FUE, Sapphire FUE, DHI, and FUT Graft Survival by Norwood Stage and Donor Difficulty (Hair Type): A Retrospective Cohort Study at Vera Clinic

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Abstract:

- ***Background:***

Technique selection in hair transplantation is commonly guided by graft-survival figures reported for individual methods in isolation. The joint influence of hair-loss severity (Norwood stage) and donor-site extraction difficulty (hair curl combined with donor skin thickness and firmness) on technique performance has not been modeled together in the existing literature. We evaluated graft survival and follicular transection across four techniques, stratified jointly by Norwood stage and donor difficulty.

- ***Methods:***

In this retrospective cohort study, de-identified clinical charts of patients undergoing follicular unit extraction (FUE), Sapphire FUE, direct hair implantation (DHI), or follicular unit transplantation (FUT) at Vera Clinic, Istanbul, between January 2023 and December 2024 were reviewed. Patients were classified into two Norwood-stage groups (Moderate, III–IV; Advanced, V–VI) and two donor-difficulty grades (Low; High), forming four patient-profile strata. The primary outcome was graft survival at 12 months; the secondary outcome was follicular transection rate. Multivariable regression, adjusted for age and graft count, produced adjusted marginal means for each technique-by-profile combination. A technique-selection matrix was derived using a prespecified statistical-adequacy threshold of n≥30 per cell.

- ***Results:***

Of 7,842 charts screened, 1,050 patients met inclusion criteria. Adjusted 12-month graft survival ranged from 85.3% to 94.6% across technique-by-profile combinations. Donor difficulty, rather than Norwood stage, was the dominant driver of transection rate, which rose from a pooled 3.0%–4.2% in Low-difficulty grafts to 6.9%–14.8% in High-difficulty grafts, with the smallest increase observed for FUT and DHI. Four of sixteen technique-by-profile cells fell below the statistical-adequacy threshold. In one of four patient-profile strata (Advanced stage with High donor difficulty), no single technique dominated on both outcomes.

- ***Conclusions:***

The technique associated with the highest point-estimate graft survival was not consistently the technique associated with the lowest transection risk, particularly in donor-difficult grafts. A joint stage-by-difficulty technique-selection matrix is proposed, with explicit flags in strata where evidence remains insufficient for a directive recommendation.

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I. INTRODUCTION

Hair transplantation technique has diversified substantially over the past two decades, and follicular unit extraction (FUE), its sapphire-blade variant, direct hair implantation (DHI), and follicular unit transplantation (FUT) are all in routine clinical use.[1] Graft survival is the outcome most frequently cited when comparing techniques, and published survival ranges for individual methods are relatively consistent across settings.[1] However, a technique's reported survival range is typically derived from a general patient population rather than from patients stratified jointly by the severity of hair loss and by donor-site extraction difficulty, leaving open the question of whether a single technique performs equally well across the full range of patients presenting for surgery.

Two independent bodies of evidence bear on this question. First, within-patient split-scalp comparisons have shown that yield, discard, and transection rates can differ meaningfully between extraction methods even when overall efficacy appears similar; a randomized split-scalp comparison of robotic extraction and conventional FUE in patients with Norwood II–IV disease found comparable safety but method-dependent differences in transection and discard rates.[2] Second, a separate line of evidence has established that donor-hair curl, together with donor skin thickness and firmness, is a strong independent predictor of follicular transection during extraction; conventional rotary-punch techniques applied to tightly curled donor hair have been associated with markedly elevated transection rates, and skin-responsive extraction approaches calibrated to curl, thickness, and firmness have been shown to reduce transection substantially relative to unadapted technique.[3,4]

These two literatures have developed largely in parallel. Norwood-stage-based technique preference is discussed principally in narrative or expert-opinion form, guided by donor-graft budget considerations, while the donor-difficulty literature has focused on extraction-tool design rather than on comparison across the full set of techniques in current clinical use. To our knowledge, no published study has modeled graft survival and transection jointly across Norwood stage and donor-difficulty grade for FUE, Sapphire FUE, DHI, and FUT within a single cohort. Vera Clinic Academy has previously reported technique-specific graft survival in an undifferentiated FUE cohort;[5] the present study extends this work by additionally stratifying by Norwood stage and donor difficulty.

The aim of this study was to compare 12-month graft survival and follicular transection rate across four hair transplant techniques, jointly stratified by Norwood stage group and donor-difficulty grade, and to derive a technique-selection matrix identifying the strata in which the evidence supports a directive recommendation and the strata in which it does not.

II. METHODS

- *Study Design and Setting*

This was a single-center retrospective cohort study conducted at Vera Clinic, Istanbul, Turkey. Patients who underwent hair transplantation between January 2023 and December 2024 were eligible for chart review. Because the primary outcome required a completed 12-month follow-up assessment, data extraction and analysis were finalized after the last enrolled patient's 12-month visit, in December 2025. Procedures were performed by a multi-surgeon team operating under a shared clinical protocol; surgical team was treated as a fixed design characteristic rather than as a modeled covariate.

- *Participants*

Eligible patients were adults who underwent a single-technique hair transplantation procedure (FUE, Sapphire FUE, DHI, or FUT) with Norwood stage III, IV, V, or VI androgenetic alopecia, and who had a completed 12-month graft-survival assessment on file. Patients were excluded if 12-month follow-up was incomplete, if Norwood staging was not documented at the time of surgery, if Norwood stage was II or VII, if donor-difficulty grading (see Variables) was not documented, or if the procedure combined more than one technique or was a revision of a prior transplant. Norwood stage II was excluded because graft numbers at this stage rarely require the technique trade-offs under study; Norwood stage VII was excluded because donor-graft supply at this stage typically necessitates multi-session planning, a distinct clinical decision problem outside the scope of this study.

Of 7,842 charts screened, 4,916 were excluded for incomplete 12-month follow-up, 892 for Norwood stage outside the III–VI range or for Ludwig-scale (female-pattern) presentations, 604 for missing donor-difficulty documentation, and 380 for combined-technique or revision procedures, leaving 1,050 patients for analysis (Table 1).

- *Variables*

Patients were classified into two Norwood-stage groups: Moderate (stage III or IV) and Advanced (stage V or VI). Donor-difficulty grade was a binary clinical classification (Low; High) assigned at the pre-operative donor assessment, incorporating hair-curl pattern together with donor-area skin thickness and firmness, consistent with the donor-grading approach described in prior work on extraction difficulty in curled and thicker donor hair.[4] Norwood-stage group and donor-difficulty grade were crossed to form four patient-profile strata. Pre-specified confounders were patient age at surgery and total graft count, both extracted from the operative record.

The primary outcome was graft survival at 12 months, defined as the percentage of transplanted grafts producing terminal hair on trichoscopic and clinical assessment. The secondary outcome was follicular transection rate, defined as the percentage of attempted grafts transected during harvest or preparation. Transection is recorded intraoperatively by

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mechanism specific to each technique (punch-related for FUE, Sapphire FUE, and DHI; strip-dissection-related for FUT); the two mechanisms were treated as producing a comparable end point (the proportion of harvested grafts rendered non-viable) rather than as directly equivalent surgical events.

➢ *Statistical Methods*

The unit of analysis was the patient, not the individual graft. Graft survival and transection rate were each calculated as a per-patient percentage (grafts surviving or transected, divided by grafts transplanted or attempted, per patient) before being entered into the regression model; consequently, no within-patient clustering adjustment was required, as each patient contributed a single outcome observation. Baseline characteristics are summarized as mean (SD) for continuous variables and n (%) for categorical variables. Graft survival and transection rate were each modeled using multivariable regression with technique, Norwood-stage group, donor-difficulty grade, and the technique-by-stage-group-by-difficulty-grade interaction as predictors, adjusted for age and graft count. Adjusted marginal means with 95% confidence intervals were derived for each technique-by-profile combination for graft survival, and for each technique-by-difficulty-grade combination for transection rate, the latter based on a preliminary model check indicating no independent stage effect on transection once donor-difficulty grade was included. Because graft survival and transection rate were modeled as continuous per-patient percentages within a linear regression framework, confidence intervals for adjusted marginal means were derived from the model's estimated residual variance (assumed homogeneous across techniques and strata) rather than from a binomial proportion variance, consistent with standard practice for percentage outcomes modeled via ordinary least squares. A cell was classified as statistically adequate for a directive recommendation only if $n \geq 30$; cells below this threshold are reported with point estimates and wide confidence intervals but are explicitly flagged as insufficient for a definitive recommendation. Analyses were performed in R version 4.3.1. No values were missing in the analytic sample, because complete documentation of the primary outcome was itself an inclusion criterion.

➢ *Ethical Considerations*

This study relied exclusively on existing clinical records; no additional visits, tests, or interventions were performed for research purposes. Full ethical considerations are stated after the Conclusions, in line with this guideline's reporting structure.

III. RESULTS

Baseline characteristics by technique and by patient-profile stratum are summarized in Table 1. FUT patients were on average older and received a higher graft count than patients receiving the other three techniques, consistent with FUT's more frequent use in Advanced-stage cases requiring higher graft volume.

Table 1. Baseline Characteristics by Technique and by Patient-Profile Stratum

Technique	N	Age, years, mean (SD)	Graft count, mean (SD)
FUE	406	33.8 (6.9)	3,180 (580)
Sapphire FUE	316	34.1 (7.2)	3,410 (610)
DHI	152	32.6 (6.5)	2,640 (520)
FUT	176	36.9 (8.1)	4,260 (690)
Overall	**1050**	**34.2 (7.1)**	**3,320 (710)**

Patient profile	N	% of cohort
Moderate (Norwood III–IV) + Low donor difficulty	441	42.0%
Moderate (Norwood III–IV) + High donor difficulty	189	18.0%
Advanced (Norwood V–VI) + Low donor difficulty	294	28.0%
Advanced (Norwood V–VI) + High donor difficulty	126	12.0%

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Adjusted 12-month graft survival by technique and patient-profile stratum is presented in Table 2a. Within the Moderate + Low-difficulty stratum, all four techniques achieved survival above 88%, with Sapphire FUE highest (94.6%, 95% CI 91.8–97.4). Survival was lower in every technique within the Advanced + High-difficulty stratum, the most demanding combination of graft volume and extraction difficulty, ranging from 85.3% (FUT) to 90.4% (Sapphire FUE, underpowered).

Table 2a. Adjusted 12-Month Graft Survival (%), Mean (95% CI), by Technique and Patient-Profile Stratum

Patient profile	FUE	Sapphire FUE	DHI	FUT
Moderate + Low	n=180 92.5 (89.4–95.6)	n=165 94.6 (91.8–97.4)	n=75 93.8 (89.6–98.0)	n=21[a] 88.0 (79.9–96.1)
Moderate + High	n=70 89.7 (84.2–95.2)	n=55 92.3 (86.9–97.7)	n=47 91.5 (85.0–98.0)	n=17[a] 86.5 (76.2–96.8)
Advanced + Low	n=110 90.8 (86.6–95.0)	n=68 93.1 (88.5–97.7)	n=21[a] 92.0 (83.5–100.0)	n=95 87.2 (81.7–92.7)
Advanced + High	n=46 87.9 (81.1–94.7)	n=28[a] 90.4 (82.1–98.7)	n=9[a] 89.0 (74.0–100.0)	n=43 85.3 (78.0–92.6)

[a] *Cell below the pre-specified statistical-adequacy threshold (n<30); point estimate shown, not used for a directive recommendation.*

Transection rate showed a strong donor-difficulty effect and no independent stage effect (Table 2b). In Low-difficulty grafts, transection rates were similar and low across all four techniques (3.0%–4.2%). In High-difficulty grafts, transection rate rose for every technique, most markedly for FUE (14.8%, 95% CI 8.4–21.2) and least for FUT (6.9%, 95% CI 0.4–13.4) and DHI (8.6%, 95% CI 1.2–16.0).

Table 2b. Adjusted Transection Rate (%), Mean (95% CI), by Technique and Donor-Difficulty Grade

Donor difficulty	FUE	Sapphire FUE	DHI	FUT
Low (n=735)	n=290 4.2% (1.9–6.5)	n=233 3.5% (1.2–5.8)	n=96 3.8% (0.2–7.4)	n=116 3.0% (0.0–6.2)
High (n=315)	n=116 14.8% (8.4–21.2)	n=83 10.2% (3.7–16.7)	n=56 8.6% (1.2–16.0)	n=60 6.9% (0.4–13.4)

The resulting technique-selection matrix is presented in Table 3. A directive recommendation was possible in three of four patient-profile strata. In the Advanced + High-difficulty stratum, only FUE and FUT met the statistical-adequacy threshold, and neither dominated the other on both outcomes: FUE showed higher survival but more than double the transection rate of FUT.

Table 3. Technique-Selection Matrix by Patient Profile

Patient profile	Recommended technique	Basis
Moderate + Low difficulty	**Sapphire FUE**	Highest adjusted survival (94.6%) and lowest transection rate (3.5%) among adequately powered techniques.
Moderate + High difficulty	**DHI**	Survival within 0.8 percentage points of the top-ranked technique; transection rate materially lower (8.6% vs 10.2–14.8%). Risk-adjusted preference over the marginally higher-survival Sapphire FUE.
Advanced + Low difficulty	**Sapphire FUE**	Highest adjusted survival (93.1%) among adequately powered techniques. FUT (87.2%, n=95) remains a viable alternative where single-session graft volume is prioritized.
Advanced + High difficulty	***No directive recommendation***	Only FUE and FUT are adequately powered; FUE shows higher survival (87.9% vs 85.3%) but more than double the transection rate (14.8% vs 6.9%). Choice depends on whether survival or graft conservation is prioritized. Sapphire FUE (90.4%, n=28) is promising but underpowered.

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IV. DISCUSSION

The principal finding of this study is that donor-difficulty grade, not Norwood stage, was the dominant driver of follicular transection risk, and that the technique with the highest point-estimate graft survival in a given patient profile was not always the technique with the lowest transection risk in that same profile. In the Moderate + High-difficulty stratum, DHI was recommended in preference to Sapphire FUE despite a marginally lower survival point estimate, because its transection rate was materially lower; this reflects a risk-adjusted trade-off that a survival-only comparison would not have surfaced.

This pattern is consistent with, and extends, two separate strands of prior evidence. Donor-difficulty effects on transection of the magnitude observed here are directionally consistent with prior work showing that curl, skin thickness, and firmness jointly predict extraction difficulty, and that adapted technique or tooling can contain transection even in difficult donor hair.[3,4] Technique-dependent differences in yield and transection under comparable clinical conditions are also consistent with prior within-patient comparative work, although that literature has compared robotic and conventional FUE rather than the four techniques modeled here.[2] To our knowledge, this is the first attempt to model graft survival and transection jointly across Norwood stage and donor-difficulty grade for FUE, Sapphire FUE, DHI, and FUT within a single cohort, which is the principal contribution of this analysis relative to the existing literature.

Several findings warrant cautious interpretation rather than firm clinical translation. First, general graft-survival factors reviewed elsewhere (dehydration, mechanical trauma, and ischemia-reperfusion injury during ex vivo handling) were not measured directly in this study and may partly explain residual differences between techniques beyond the modeled variables.[1] The general 90–95% survival range reported for FUE-family techniques in the literature reflects typical clinical conditions; the below-range point estimates observed here for FUE in the Moderate + High-difficulty and Advanced + High-difficulty strata are consistent with the compounding effect of donor extraction difficulty on punch-based harvesting, rather than a deviation from expected technique performance under comparable conditions. Second, in the Advanced + High-difficulty stratum, the absence of a dominant technique is itself a clinically meaningful result: it indicates that, at the limits of graft volume and donor difficulty, technique selection should be individualized around whether survival or graft conservation is the higher clinical priority for a given patient, rather than resolved by a single default recommendation.

This study has several limitations. It is retrospective and non-randomized; technique was selected by clinician judgment based on stage, donor difficulty, and patient preference, and confounding by indication cannot be excluded beyond the two measured confounders of age and graft count. Unlike within-patient split-scalp designs, this was a between-patient comparison, which cannot fully separate technique effects from unmeasured patient-level or surgeon-level factors.[2] Four of sixteen technique-by-profile survival cells, and none of the transection cells, fell below the pre-specified adequacy threshold, most often reflecting genuinely low clinical use of a technique in a given profile (for example, DHI in Advanced-stage cases) rather than a sampling artifact; these cells are reported for transparency but were excluded from directive recommendations. The study was conducted at a single center, and donor-difficulty grading, while modeled on a previously described clinical classification, was not independently validated in this cohort.[4]

These findings have practical implications for pre-operative counseling and technique planning. Where the evidence was adequate, the technique-selection matrix in Table 3 offers a stratified starting point for discussion between clinician and patient. Where the evidence was inadequate (principally in donor-difficult, high-graft-volume cases), the appropriate response is not to force a recommendation but to prioritize expansion of that stratum in future data collection, and in the interim to base technique choice explicitly on whichever of survival or graft conservation the individual patient's circumstances make the higher priority.

V. CONCLUSIONS

In this retrospective cohort, donor-difficulty grade was the dominant driver of follicular transection risk across four hair transplant techniques, and the technique with the highest graft survival was not consistently the technique with the lowest transection risk. A stage-by-difficulty technique-selection matrix is proposed for clinical discussion, with an explicit flag for the one patient-profile stratum in which the current evidence does not support a single directive recommendation: Advanced stage combined with High donor difficulty.

- *Ethical Considerations*

This retrospective cohort analysis was based on de-identified clinical charts, intraoperative logs, and 12-month follow-up records collected as part of routine post-operative care for patients undergoing FUE, Sapphire FUE, DHI, or FUT at Vera Clinic. Norwood staging, donor-difficulty grading, and graft-survival and transection data were extracted from these existing clinical records; no additional visits, tests, or interventions were performed for the purposes of this study. Patients were informed at the time of treatment that anonymized clinical data collected during standard pre-operative assessment and follow-up visits could be used for research and quality-improvement purposes. All patient records were anonymized and de-identified prior to analysis, in accordance with the principles of the Declaration of Helsinki.

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➢ *Conflict of Interest*

All authors are affiliated with Vera Clinic Academy, where the study was conducted. The clinic provided patient records, surgical facilities, and follow-up infrastructure. The authors declare no other competing interests. No external funding was received. Data analysis and manuscript preparation were conducted independently of marketing, sales, or commercial decision-making functions of the clinic.

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➢ *Data Availability*

De-identified data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to ethics committee review.

➢ *Author Contributions*

Vera Clinic Academy conceived the study, supervised data collection, performed data extraction and statistical analysis, and drafted the manuscript.

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