Clinical, Cosmetic and Investigational Dermatology

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ORIGINAL RESEARCH

Comparative Evaluation of Buffy Coat–Derived and Apheresis Platelet-Rich Plasma in the Treatment of Androgenetic Alopecia: Laboratory and Clinical Insights

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Background: Androgenetic alopecia (AGA) is the most common type of hair loss, and platelet-rich plasma (PRP) has emerged as a promising therapy. However, preparation methods may influence clinical outcomes.

Objective: To compare buffy coat and apheresis PRP in terms of laboratory characteristics and treatment efficacy in AGA, and to identify predictors of response.

Methods: A retrospective analysis was conducted on 747 PRP preparations (514 buffy coat, 233 apheresis) and 163 AGA patients who were eligible for final analysis after screening (87 buffy coat, 76 apheresis). Laboratory indices and PRP parameters were assessed. Clinical efficacy was evaluated by trichoscopy and patient-reported outcomes. Logistic regression was used to determine independent predictors.

Results: Apheresis PRP required greater blood volumes and yielded higher platelet concentration (1242×10^9/L vs 1079×10^9/L, $P<0.001$), total platelet counts, and purity, while buffy coat achieved higher recovery rates. Both methods significantly improved hair density, shaft diameter, and follicular parameters, with no significant differences between groups. Patient-reported improvement was higher in the buffy coat group (51.7% vs 46.1%). Logistic regression identified preparation method (buffy coat: OR=3.41, 95% CI: 1.21–9.65, P=0.021) and treatment frequency (OR=2.01 per session, 95% CI: 1.32–3.07, P=0.001) as independent predictors of response. Sex and platelet concentration showed no significant associations.

Conclusion: Both buffy coat and apheresis PRP are effective for AGA. Buffy coat PRP was associated with greater subjective improvement despite lower platelet counts, suggesting that platelet number alone does not determine efficacy. Repeated treatments significantly enhance outcomes, highlighting the importance of treatment frequency in PRP therapy.

Keywords: androgenetic alopecia, platelet-rich plasma, buffy coat, apheresis

Introduction

Androgenetic alopecia (AGA) is the most common form of hair loss, affecting both men and women and exerting significant psychosocial and quality-of-life burdens.[1] It is characterized by progressive miniaturization of hair follicles under the influence of androgens in genetically predisposed individuals, typically manifesting as receding frontal hairlines, vertex thinning in males, and diffuse central thinning in females. Epidemiological studies have consistently shown that the prevalence of AGA rises with advancing age, making it a widespread condition across both sexes. The cosmetic and psychological consequences of AGA are considerable, often leading to reduced self-esteem, anxiety, and social withdrawal, thereby underscoring the importance of effective therapeutic strategies.

https://doi.org/10.2147/CCID.S606548
Received: 3 March 2026
Accepted: 4 May 2026
Published: 12 May 2026

Current treatment options for AGA, such as oral finasteride and topical minoxidil, have variable efficacy, influenced by patient adherence, contraindications, and concerns over side effects.[2] Finasteride, a 5α-reductase inhibitor, reduce dihydrotestosterone levels and slow hair follicle miniaturization; Minoxidil, a topical vasodilator, can stimulate hair growth. However, both treatments do not guarantee satisfactory results for all patients, underscoring the demand for alternative and adjunctive therapies.

Platelet-rich plasma (PRP) has emerged as a promising therapeutic modality for AGA.[3] It is obtained from the patient's blood, either through centrifugation or apheresis, and contains growth factors such as platelet-derived growth factor (PDGF), vascular endothelial growth factor (VEGF), and insulin-like growth factor-1 (IGF-1), which stimulate dermal papilla cell proliferation, prolong the anagen phase, and promote angiogenesis around hair follicles.[4] Through these mechanisms, PRP is believed to counteract follicular miniaturization and induce the transition of vellus hairs to terminal hairs. Clinical studies have reported variable efficacy of PRP in AGA, influenced by factors such as PRP preparation methods, platelet concentration, and leukocyte or red blood cell contamination.[5,6]

Two main techniques for PRP preparation are commonly used: buffy coat centrifugation and apheresis. While buffy coat is simple and cost-effective, apheresis can collect larger PRP volumes with higher platelet purity, making it more suitable for repeated treatments or protocols requiring higher doses.[7] However, comparative data on their efficacy in AGA are limited, and the clinical implications of differences in laboratory parameters between the two approaches remain unclear.

The present retrospective study aimed to evaluate the impact of two PRP preparation methods—buffy coat and apheresis—on laboratory parameters and clinical outcomes in patients with AGA. We further assessed potential predictors of treatment efficacy, including PRP characteristics and treatment frequency, to provide insights into optimizing PRP protocols for hair restoration.

Methods and Materials

Study Design and Patient Population

This retrospective study was conducted between February 2023 and July 2025 in the Department of Dermatology and the Department of Blood Transfusion at the First People's Hospital of Foshan. A total of 747 PRP preparations were reviewed (514 buffy coat and 233 apheresis). For clinical efficacy analysis, 355 patients with androgenetic alopecia (AGA) were initially screened; after exclusion for incomplete data, treatment discontinuation, or loss to follow-up, 163 patients remained eligible (87 buffy coat, 76 apheresis). Diagnosis of AGA was established based on clinical assessment and trichoscopic findings. Exclusion criteria included hematological disorders, systemic diseases affecting hair, anticoagulant use, pregnancy or lactation, and refusal to consent. Group assignment was not randomized. The choice of PRP preparation method (buffy coat vs apheresis) was made according to real-world clinical practice, including service availability, clinician–patient discussion, and patient preference. Therefore, selection bias cannot be fully excluded.

Platelet-Rich Plasma (PRP) Preparation

For the buffy coat method, 80 mL of peripheral venous blood was collected using the Dracula PRP preparation kit, and 2 mL of EDTA-anticoagulated blood was reserved for complete blood count (CBC). The first centrifugation was performed at 1100–1200 g for 8 minutes, followed by 2100–2200 g for 5 minutes. The buffy coat fraction (25–30 mL) was transferred, mixed thoroughly, and subjected to a second centrifugation at 320–350 g for 8 minutes. The upper plasma fraction containing concentrated platelets (9–12 mL) was collected for injection.

For the apheresis method, PRP was prepared using the COM.TEC cell separator (Fresenius Kabi, Germany) according to standard protocols. The target platelet concentration was 1000–1500 $\times 10^9$/L, with a total yield of 42 mL. Two milliliters were analyzed for CBC, and the remaining 40 mL was aseptically divided into four bags. Ten milliliters were injected on the same day, while 30 mL was cryopreserved at –80 °C and later thawed prior to subsequent sessions according to institutional practice. Because fresh administration and freeze–thaw exposure may affect platelet integrity and growth-factor release, this procedural difference was considered a major potential confounder when interpreting between-group comparisons.All hematological parameters of whole blood and PRP, including platelet count, leukocyte count, and red blood cell count, were analyzed using the Mindray BC-5390CRP automated hematology analyzer.

AGA Treatment Procedure

All patients underwent baseline photography and dermoscopic examination prior to treatment. Topical anesthesia with 5% lidocaine cream was applied for 1 hour, followed by scalp disinfection with 75% alcohol. PRP was injected intradermally into alopecic scalp regions using a 1 mL syringe with a 34-gauge needle. Each injection delivered approximately 0.05 mL at 0.5 cm intervals, to a depth sufficient to induce pinpoint bleeding and papules. The average dose per session was 9–12 mL. Sessions were scheduled once a month. Patients in the buffy coat group and the apheresis group received at least 2 sessions. Treatment frequency was therefore not fully standardized in this retrospective cohort and was accounted for in multivariable models.

Outcome Evaluation

Efficacy was evaluated using both objective and subjective measures. Laboratory parameters included platelet count (PLT), leukocyte count (WBC), red blood cell count (RBC), hemoglobin (Hb), mean corpuscular volume (MCV), and hematocrit (Hct). Dermoscopic assessments were performed at baseline (pre-treatment) and one month after the final PRP session (post-treatment) using a polarized digital dermoscope (BN-PFMF-8001D, BEINING) at 50× magnification. Parameters recorded included hair density, hair shaft diameter, terminal-to-vellus ratio, and follicular unit counts. Quantitative assessments were performed on standardized images obtained from the same scalp area at each visit. Hair density and follicular unit counts were evaluated within a fixed field of view, and hair shaft diameter was measured using calibrated image-based measurement tools. To minimize observer bias, evaluations were performed by trained assessors following a predefined protocol, with discrepancies resolved by consensus. All dermoscopic images were standardized and obtained from the same affected scalp area of each patient under identical lighting and positioning conditions. Regarding outcome evaluation, objective assessments were conducted in a blinded manner. After the first treatment, patients were asked to complete the questionnaire before each subsequent treatment to assess their progress. Efficacy was self-assessed using a simple, self-designed questionnaire, categorizing the results into three levels: No/Slight Effect, Moderate Effect, and Significant Effect. This systemically evaluated changes in hair shedding, scalp oiliness, and new hair growth.

Statistical Analysis and Visualization

All statistical analyses were performed using R (version 4.4.1) and IBM SPSS Statistics. Data visualization was conducted with the *ggplot2* package (version 3.2.8). Continuous variables were tested for normality and expressed as median with interquartile range (IQR). Comparisons between groups were performed using the non-parametric Mann–Whitney *U*-test. Categorical variables were analyzed with the chi-square test. Multivariate logistic regression analysis was applied to identify independent predictors of clinical improvement. The selection was based on clinical rationale and existing research on androgenetic alopecia and PRP treatment. Sex-stratified multinomial logistic regression analyses (male and female separately) were conducted using the same covariates as the overall model (excluding sex). To formally assess effect modification by sex, a Method×Sex interaction term was added to the overall multinomial model and evaluated using likelihood ratio tests. A two-sided p-value < 0.05 was considered statistically significant.

Results

Baseline Characteristics

A total of 747 platelet-rich plasma (PRP)preparation records were analyzed, including 514 prepared by the buffy coat method and 233 by apheresis. Gender distribution was balanced, with a higher proportion of females in the buffy coat group (57.8%) and males in the apheresis group (51.1%). Compared with buffy coat, the apheresis group exhibited significantly greater body weight (65 vs 60 kg, $P<0.01$) and hemoglobin concentration (146 vs 133 g/L, $P<0.001$). Baseline platelet counts were comparable between groups (250 vs 249 $\times 10^9$/L, $P=0.796$).

Sex-stratified analysis confirmed these trends. In males, hemoglobin (155.5 vs 146 g/L, $P<0.001$) and leukocyte counts (6.41 vs 5.73 $\times 10^9$/L, $P<0.01$) were higher in the apheresis group. In females, hemoglobin was also elevated with apheresis (133 vs 126 g/L, $P<0.001$). Platelet counts did not differ significantly by sex. Overall, apheresis was associated

Table 1 Demographic and Hematological Parameters Stratified by Method and Gender

Method	Gender (n, %)			Age (yr)	Height (cm)	Weight (kg)	WBC ($\times10^9$/L)	HB (g/L)	HCT (%)	MCV (fL)	Platelet ($\times10^9$/L)
Buffy coat	Total	514	–	37 (30,44)	164 (158,170)	60** (54,70)	5.85 (4.94,7.05)	133*** (123,145)	39.9 (37.4,43.2)	89.7 (86.4,92.0)	250 (223,280)
	Male	215	41.82	34 (28,40)	170 (167,176)	70 (62,76)	5.73## (4.91,7.04)	146#### (141,152)	43.7 (41.9,45.3)	89.3 (86.3,91.8)	242 (217,272)
	Female	299	58.17	39 (33,49)	160 (156,163)	55 (51,60)	5.93 (4.96,7.07)	126$$$ (118,131)	37.8 (35.9,39.4)	89.95 (86.5,92.1)	259.5 (229,292)
Apheresis	Total	233	–	36 (29,42)	168 (159,173)	65 (55,73)	5.97 (4.93,7.00)	146 (134,156)	42.5 (39.2,45.0)	88.1 (84.5,90.6)	249 (208,297.5)
	Male	119	51.07	33.5 (27,40)	172.25 (170,176)	71.5 (65,77.5)	6.405 (5.35,7.72)	155.5 (147,162)	44.85 (43.5,47.7)	87.75 (84.5,90.3)	248 (208,298)
	Female	114	48.93	38 (33,46)	159 (157,163)	55 (51,60)	5.32 (4.75,6.48)	133 (127,141)	38.9 (37.1,41.1)	88.2 (85.9,91.4)	254 (208,297)

Notes: *Indicates comparison between Buffy coat total and Apheresis total; #indicates comparison between Buffy coat male and Apheresis male; $Indicates comparison between Buffy coat female and Apheresis female. *,#,$Means p<0.05, **,##,$$Means p<0.01, ***,####,$$$Means p<0.001. Baseline characteristics of participants, including demographic and blood parameters, are compared between the buffy coat and apheresis groups. Data are expressed as median (interquartile range). Statistical comparisons were performed between groups and genders. $p < 0.05$ was considered significant.

Abbreviations: WBC, white blood cell count; HB, hemoglobin; HCT, hematocrit; MCV, mean corpuscular volume.

with higher hemoglobin and leukocyte indices, while platelet levels remained consistent across groups, ensuring comparable baseline platelet status for subsequent outcome evaluation (Table 1).

PRP Preparation Parameters

Marked and statistically significant differences were noted between the two PRP preparation techniques (Table 2). The apheresis method required substantially larger volumes of whole blood collection [855 mL vs 80 mL, P<0.001] and, as a result, generated markedly greater PRP volumes [40 mL vs 10.5 mL, P<0.001]. In addition, the apheresis group achieved significantly higher platelet concentrations [1242×10^9/L vs 1079×10^9/L, P<0.001], which was reflected in a markedly greater overall platelet yield [49.88×10^9 vs 11.56×10^9, P<0.001]. Conversely, the buffy coat method demonstrated clear superiority in platelet recovery efficiency [57.01% vs 24.00%, P<0.001], indicating that while absolute yields were lower, a greater proportion of platelets from the original sample were retained.

With regard to product purity, PRP derived from apheresis contained significantly fewer leukocytes [0.28×10^9/L vs 0.40×10^9/L, P<0.001] and showed reduced leukocyte contamination [0.21% vs 0.91%, P<0.001] as well as lower red blood cell contamination [0.0005% vs 0.0014%, P<0.001]. Sex-stratified comparisons highlighted additional differences: in the buffy coat group, women produced slightly larger PRP volumes [11 mL vs 10.5 mL, P<0.05], while men showed higher platelet concentration folds [4.44 vs 4.20, P<0.05]. Within the apheresis group, men consistently achieved both higher platelet concentration folds [5.29 vs 4.76, P<0.01] and greater total platelet yield [54.1×10^9 vs 48.92×10^9, P<0.01], suggesting a possible sex-related influence on PRP yield.

Clinical Efficacy Evaluation

Among 355 initially enrolled patients (170 buffy coat, 185 apheresis), 192 were excluded due to incomplete data, treatment discontinuation, or loss to follow-up, yielding 163 evaluable cases (87 buffy coat, 76 apheresis) (Figure 1). Baseline demographic features, including age, height, and weight, were comparable between groups (all P>0.05), supporting group homogeneity. Patient self-assessment demonstrated a favorable trend toward greater clinical benefit with buffy coat PRP. In this group, more than half of patients (51.7%) reported significant improvement, compared with 46.1% in the apheresis group, while fewer patients experienced no or slight effect (24.1% vs 34.2%). Moderate improvements were similar between groups (24.1% vs 19.7%). Sex-stratified analysis showed descriptive differences in self-reported efficacy by sex: male patients numerically favored buffy coat PRP (53.7% significant improvement vs 39.5% in apheresis), whereas female patients showed a small numerical advantage for apheresis (52.6% vs 50.0%) (Table 3).

Trichoscopic assessment demonstrated that both preparation methods yielded significant clinical benefits in hair parameters (Figure 2). In the apheresis group, hair density improved from 104 to 116 hairs/cm^2, mean shaft diameter increased from 51 μm to 56 μm, and the terminal-to-vellus ratio shifted favorably (all P<0.05). Comparable yet numerically greater changes were observed in the buffy coat group, where hair density increased from 102 to 118

Table 2 Platelet-Rich Plasma (PRP) Preparation Parameters Stratified by Method and Gender

Method	Gender (n, %)			Blood Volume (mL)	PRP Volume (mL)	PRP Platelets ($\times10^9$/L)	PRP WBC ($\times10^9$/L)	PRP RBC ($\times10^{12}$/L)	Platelet Recovery Rate (%)	Platelet Concentration Fold	Total Platelet Yield ($\times10^9$)	WBC Contamination Rate (%)	RBC Contamination Rate (%)
Buffy coat	Total	514	–	80 (80, 80)	10.5 (10, 11.5)	1079 *** (926, 1235)	0.4 *** (0.25, 0.71)	0.01 (0.01, 0.02)	57.01*** (51.06, 62.71)	4.30*** (3.90, 4.71)	11.56*** (9.74, 13.56)	0.91*** (0.55, 1.55)	0.0014*** (0.0012, 0.0021)
	Male	215	42.02	80 (80, 80)	10.5 (10, 11)	1079 ### (929, 1206)	0.41 ### (0.26, 0.83)	0.01 (0.01, 0.01)	58.65#### (51.78, 64.40)	4.44 ### (4.07, 4.80)	11.27#### (9.66, 13.23)	0.98#### (0.59, 1.73)	0.0012#### (0.0011, 0.0015)
	Female	299	57.78	80 (80, 80)	11 (10, 12)	1078.5$^{\$\$\$}$ (926, 1244)	0.385$^{\$\$\$}$ (0.23, 0.67)	0.01 (0.01, 0.02)	55.89$^{\$\$\$}$ (50.75, 61.92)	4.2$^{\$\$\$}$ (3.81, 4.61)	11.785 $^{\$\$\$}$ (9.86, 13.70)	0.9$^{\$\$\$}$ (0.52, 1.41)	0.0015$^{\$\$\$}$ (0.0013, 0.0024)
Apheresis	Total	233	–	855 (771.5, 929.0)	40 (40, 40)	1242 (1073.5, 1429)	0.28 (0.16, 0.41)	0.01 (0.01, 0.02)	24.00 (21.23, 26.73)	5.02 (4.46, 5.61)	49.88 (43.12, 57.70)	0.21 (0.13, 0.36)	0.0005 (0.0004, 0.0008)
	Male	119	51.07	854.5 (772, 930)	40 (40, 40)	1319.5 (1131, 1509)	0.29 (0.15, 0.45)	0.01 (0.01, 0.02)	25.45 (22.18, 27.80)	5.29 (4.68, 5.99)	54.1 (45.24, 60.84)	0.2 (0.10, 0.35)	0.0005 (0.0004, 0.0007)
	Female	114	48.93	857 (768, 922)	40 (40, 40)	1206 (1052, 1338)	0.27 (0.17, 0.41)	0.01 (0.01, 0.02)	22.2 (20.69, 25.30)	4.76 (4.09, 5.18)	48.92 (42.52, 53.64)	0.23 (0.15, 0.36)	0.0005 (0.0004, 0.0010)

Notes: Data are presented as median (interquartile range). *indicates comparison between Buffy coat total and Apheresis total; #Indicates comparison between Buffy coat male and Apheresis male; $ indicates comparison betweenBuffy coat female and Apheresis female. *,#,$Means p<0.05, **,##,$Means p<0.01, ***,####,$Means p<0.001.This table summarizes PRP preparation parameters, including blood and PRP volumes, platelet and leukocyte concentrations, platelet recovery rate, and contamination ratios, in male and female donors using buffy coat and apheresis methods.

Abbreviations: PRP, platelet-rich plasma; WBC, white blood cell; RBC, red blood cell.

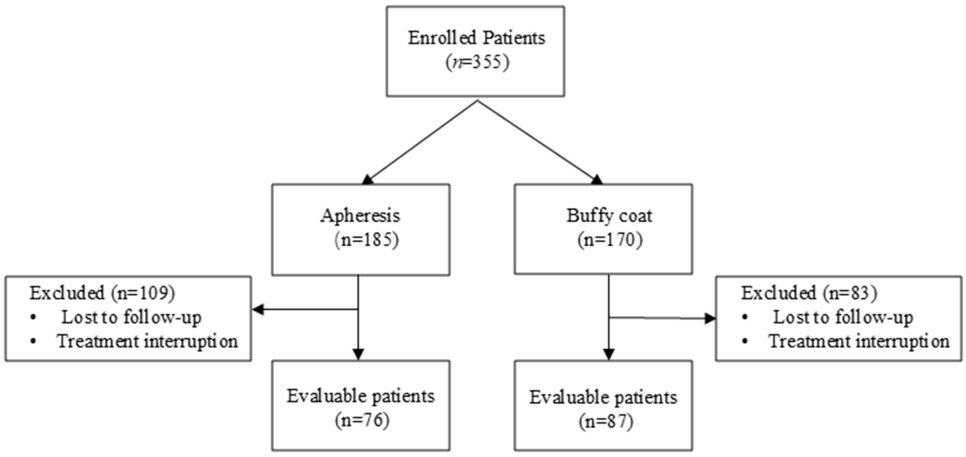

Figure 1 Flowchart of patient enrollment and study design. A total of 355 patients with androgenetic alopecia (AGA) were initially screened. After excluding 192 patients due to incomplete information, 163 patients remained eligible for analysis. Among them, 185 patients received apheresis-derived PRP and 170 patients received buffy coat–derived PRP. Following additional exclusions for loss to follow-up or treatment interruption, 76 patients in the apheresis group and 87 patients in the buffy coat group were included in the final analysis.

hairs/cm^2, shaft diameter rose from 62 μm to 66 μm, and terminal hair proportion was markedly elevated (all P<0.001). Despite these trends, statistical comparisons revealed no significant difference between the two methods.

Factors Associated with Treatment Outcomes

Analysis of sex distribution revealed no significant association with treatment efficacy in the overall cohort (χ^2=0.39, P>0.05), and similar findings were observed in subgroup analyses stratified by preparation method (buffy coat: χ^2=0.98, P>0.05; apheresis: χ^2=2.17, P>0.05). This indicates that gender was not a determinant of clinical response in this study. In contrast, treatment frequency demonstrated a near-significant trend in the buffy coat group (χ^2=17.42, P=0.066), suggesting a potential cumulative or dose–response relationship, whereas no such association was observed in the apheresis group (χ^2=0.33, P>0.05). Platelet concentration itself was not correlated with clinical outcomes in either group (buffy coat: χ^2=4.22, P>0.05; apheresis: χ^2=2.72, P>0.05), highlighting that platelet quantity alone may not be a sufficient predictor of therapeutic benefit (Table 4).

Multivariate logistic regression (Table 5) identified both PRP preparation method and treatment frequency as independent predictors of efficacy. Compared with apheresis, buffy coat PRP conferred greater odds of achieving significant improvement (OR=3.41, 95% CI: 1.21–9.65, P=0.021). Moreover, each additional treatment session nearly

Table 3 Demographic Characteristics and Self-Assessed Efficacy of Hair Restoration Stratified by Method and Gender

Method	Gender (n, %)			Age (yr)	Height (cm)	Weight (kg)	Efficacy Self-Assessment (n, %)		
							No/Slight Effect	Moderate Effect (Reduced Hair Loss/Seborrhea)	Significant Effect (Hair Growth)
Buffy coat	Total	87	-	36 (29, 40.5)	164 (158, 170)	60 (53, 70)	21 (24.14)	21 (24.14)	45 (57.12)
	Male	41	47.13	35 (29, 40)	170 (167, 175.5)	70 (60, 76.5)	8 (19.51)	11 (26.83)	22 (53.66)
	Female	46	52.87	36.5 (29.5, 43.5)	158 (155, 161)	55 (51, 59)	13 (28.26)	10 (21.74)	23 (50.00)
Apheresis	Total	76	-	35.5 (30, 41)	167 (160, 173)	62.5 (56, 72)	26 (34.21)	15 (19.74)	35 (46.05)
	Male	38	50	32 (29, 38)	173 (170, 176)	70 (65, 75)	16 (42.11)	7 (18.42)	15 (39.47)
	Female	38	50	39 (32, 43)	160 (157, 164)	56 (52, 60)	10 (26.32)	8 (21.05)	20 (52.63)

Notes: Data for age, height, and weight are presented as median (interquartile range); efficacy self-assessment is presented as number (percentage). Patient characteristics and subjective efficacy outcomes were evaluated separately by PRP preparation method and gender. Efficacy categories were defined as no/slight effect, moderate effect (reduced hair loss or seborrhea), and significant effect (hair growth).

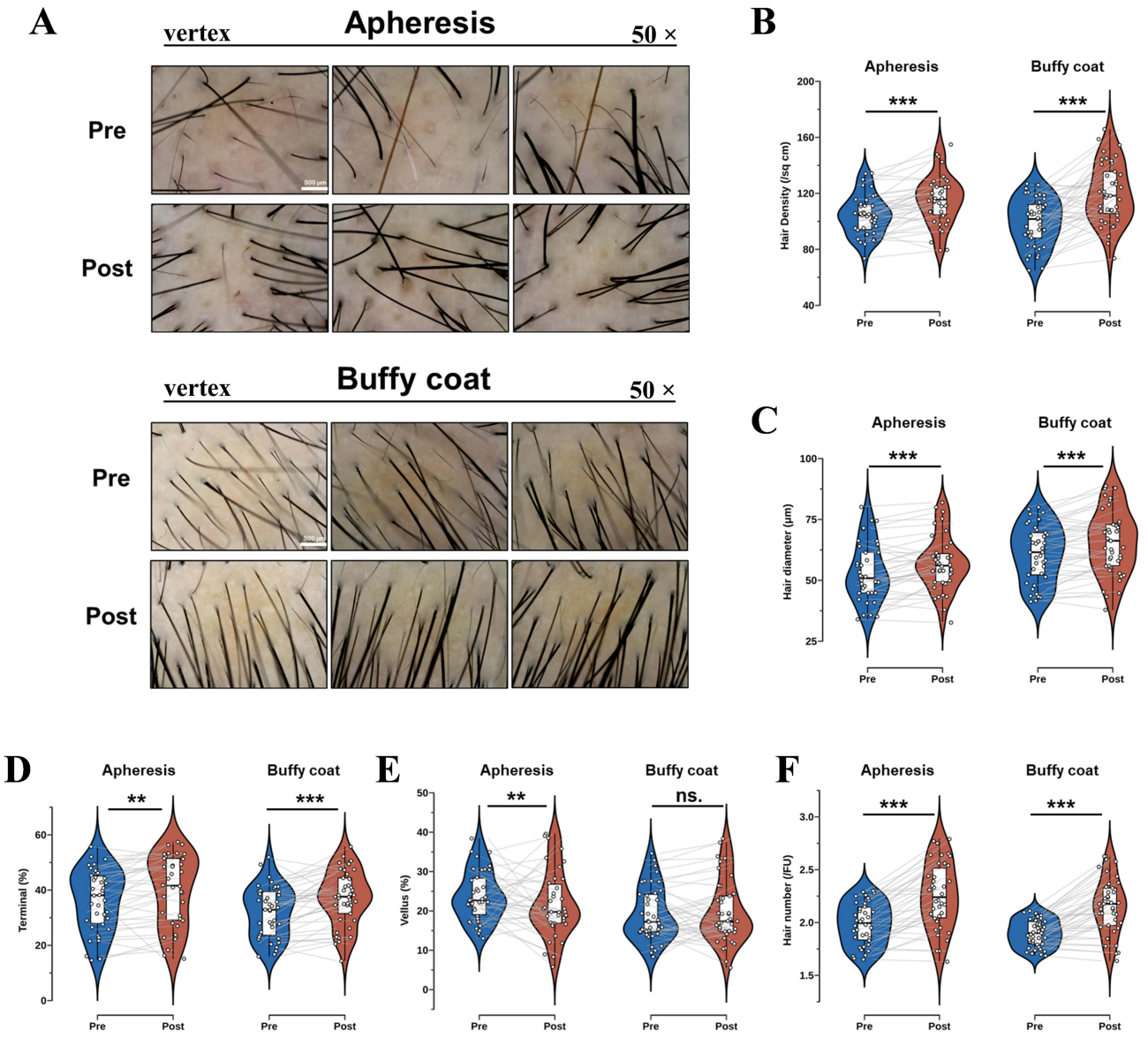

Figure 2 Clinical and dermoscopic outcomes after PRP treatment in AGA patients. (**A**) Representative dermoscopic images (50× magnification) before and after treatment in both the apheresis and buffy coat groups show visible increases in hair density and shaft thickness. Quantitative analyses demonstrate significant improvements in (**B**) hair density, (**C**) hair shaft diameter, (**D**) terminal hair ratio, (**E**) vellus hair ratio, (**F**) follicular unit counts after treatment compared with baseline in both groups. Data are presented as violin plots with paired pre- and post-treatment values. Statistical significance: **p < 0.01, ***p < 0.001; ns, not significant.

doubled the likelihood of improvement (OR=2.01, 95% CI: 1.32–3.07, P=0.001). To evaluate whether these apparent differences reflect sex-specific treatment effects, we performed sex-stratified multinomial logistic regression analyses (Tables S1 and S2) and formally tested a Method×Sex interaction in the overall model. The interaction was not statistically significant (P=0.176) (Table S3), indicating no strong evidence of effect modification by sex; therefore, subgroup differences should be interpreted cautiously as exploratory.

Discussion

This study retrospectively compared two major platelet-rich plasma (PRP) preparation methods—buffy coat and apheresis—for the treatment of androgenetic alopecia (AGA). Both methods resulted in significant improvements in hair density, follicular unit counts, and hair shaft diameter, supporting the growing body of evidence that PRP is

https://doi.org/10.2147/CCID.S606548

Table 4 Distribution of Follow-Up Outcomes, Gender, Treatment Frequency, and Platelet (PLT) Concentration by Method

Method	Efficacy Self-Assessment	n (%)	Gender (n, %)		Treatment Frequency (n, %)						PLT Concentration (n, %)		
			Male	Female	2	3	4	5	6	>6	<1000	1000–1500	>1500
Total	No/Slight Effect	47 (28.83)	24 (51.06)	23 (48.94)	10 (21.28)	3 (6.38)	31 (65.96)	2 (4.26)	1 (2.13)	0 (0)	18 (38.30)	25 (53.19)	4 (8.51)
	Moderate Effect (Reduced Hair Loss/Oil)	36 (22.09)	18 (50.00)	18 (50.00)	8 (22.22)	5 (13.89)	15 (41.67)	2 (5.56)	2 (5.56)	4 (11.11)	9 (25.00)	23 (63.89)	4 (11.11)
	Significant Effect (Hair Growth)	80 (49.08)	37 (46.25)	43 (53.75)	6 (7.50)	10 (12.50)	43 (53.75)	6 (7.50)	3 (3.75)	12 (15.00)	17 (21.25)	57 (71.25)	6 (7.50)
Buffy coat	No/Slight Effect	21 (24.14)	8 (38.10)	13 (61.90)	10 (47.62)	2 (9.52)	7 (33.33)	1 (4.76)	1 (4.76)	0 (0)	11 (52.38)	9 (42.86)	1 (4.76)
	Moderate Effect (Reduced Hair Loss/Oil)	21 (24.14)	11 (52.38)	10 (47.62)	8 (38.10)	5 (23.81)	2 (9.52)	1 (4.76)	2 (9.52)	3 (14.29)	8 (38.10)	12 (57.14)	1 (4.76)
	Significant Effect (Hair Growth)	45 (51.72)	22 (48.89)	23 (51.11)	6 (13.33)	10 (22.22)	19 (42.22)	4 (8.89)	3 (6.67)	3 (6.67)	13 (28.89)	31 (68.89)	1 (2.22)
Apheresis	No/Slight Effect	26 (34.21)	16 (61.54)	10 (38.46)	0 (0)	1 (3.85)	24 (92.31)	1 (3.85)	0 (0)	0 (0)	7 (26.92)	16 (61.54)	3 (11.54)
	Moderate Effect (Reduced Hair Loss/Oil)	15 (19.74)	7 (46.67)	8 (53.33)	0 (0)	0 (0)	13 (86.67)	1 (6.67)	0 (0)	1 (6.67)	1 (6.67)	11 (73.33)	3 (20.00)
	Significant Effect (Hair Growth)	35 (46.05)	15 (42.86)	20 (57.14)	0 (0)	0 (0)	24 (68.57)	2 (5.71)	0 (0)	9 (25.71)	4 (11.43)	26 (74.29)	5 (14.29)

Notes: Data are presented as number (percentage). This table presents follow-up evaluation outcomes, including treatment frequency, gender distribution, and platelet concentration levels, for patients receiving PRP prepared by different methods.

Abbreviation: PLT, platelet.

https://doi.org/10.2147/CCID.S606548

Table 5 Parameter Estimates for Multinomial Logistic Regression (Reference: No/Slight Effect [Grade 1])

Follow-Up Grade	Predictor	*β*	Std. Error	Wald	*df*	*P*-value	Exp(β)	95% CI for Exp(β) (Lower, Upper)
Grade 2 (Moderate Effect)	Intercept	1.261	8.202	0.024	1	0.878	-	-
	Method (Apheresis vs Buffy coat)	1.185	0.609	3.784	1	0.052	3.271	(0.991, 10.795)
	Gender (Female vs Male)	−0.25	0.741	0.001	1	0.973	0.975	(0.228, 4.166)
	Height	−0.018	0.043	0.184	1	0.668	0.982	(0.902, 1.068)
	Weight	−0.01	0.027	0.132	1	0.716	0.99	(0.939, 1.044)
	Age	−0.051	0.028	3.394	1	0.065	0.95	(0.900, 1.003)
	Treatment Frequency	0.528	0.232	5.156	1	0.023	1.695	(1.075, 2.672)
	PRP Platelet	0	0.001	0.089	1	0.765	1	(0.998, 1.002)
	PRP WBC	0.011	0.805	0	1	0.989	1.011	(0.209, 4.892)
	PRP RBC	−4.674	34.758	0.017	1	0.895	0.01	$(2.677\times10^{-32}, 3.974\times10^{-27})$
Grade 3 (Significant Effect)	Intercept	2.693	7.283	0.137	1	0.712	-	-
	Method (Apheresis vs Buffy coat)	1.227	0.531	5.353	1	0.021	3.412	(1.206, 9.652)
	Gender (Female vs Male)	−0.145	0.646	0.05	1	0.823	0.865	(0.244, 3.071)
	Height	−0.025	0.039	0.401	1	0.526	0.976	(0.903, 1.053)
	Weight	−0.026	0.025	1.065	1	0.302	0.975	(0.928, 1.023)
	Age	−0.028	0.024	1.303	1	0.254	0.973	(0.928, 1.020)
	Treatment Frequency	0.7	0.215	10.619	1	0.001	2.014	(1.322, 3.069)
	PRP Platelet	0	0.001	0.154	1	0.695	1	(0.999, 1.002)
	PRP WBC	−0.284	0.725	0.154	1	0.695	0.752	(0.182, 3.118)
	PRP RBC	−4.581	29.652	0.024	1	0.877	0.01	$(5.902\times10^{-28}, 1.780\times10^{-23})$

Notes: Reference category for follow-up grade: No/Slight Effect (Grade 1); for method: Apheresis (1); for gender: Male (1). Correlation coefficients between PRP composition (platelet count, WBC, RBC, platelet recovery rate) and clinical improvement scores are displayed. Significant associations were identified using Spearman correlation test, with $p < 0.05$ considered statistically significant.

Abbreviations: PRP, platelet-rich plasma; WBC, white blood cell; RBC, red blood cell.

a promising therapeutic option for patients suffering from AGA. Notably, patients who received buffy coat PRP tended to report higher subjective satisfaction with treatment outcomes, despite the apheresis method consistently demonstrating superior laboratory performance, including higher platelet concentration and reduced leukocyte contamination. This discrepancy highlights the complex relationship between laboratory parameters of PRP and actual clinical benefits, suggesting that in vivo efficacy is influenced by multiple interacting factors rather than a single measurable parameter.

Apheresis-derived PRP showed advantages in laboratory indices such as platelet yield, concentration, and purity. However, buffy coat PRP did not show inferiority in clinical efficacy and even exhibited a trend toward greater subjective improvement. This partial inconsistency between laboratory outcomes and clinical observations suggests that platelet counts alone cannot be considered the central determinant of therapeutic efficacy. Other factors, such as growth factor release, platelet activation, and the presence of leukocytes and plasma proteins, may play more central roles in hair follicle regeneration.[8–10] Although early studies on PRP technology indicated that cryopreservation and delays in PRP administration could compromise platelet membrane integrity, reduce viability, and impair the release of essential growth factors such as platelet-derived growth factor (PDGF) and vascular endothelial growth factor (VEGF), more recent research has shown that advancements in preparation and storage techniques have significantly improved outcomes. Specifically, short-term cryopreservation of PRP at −80°C for 6–12 months has been found to maintain platelet count, platelet activation, and growth factor release, with no significant differences compared to fresh preparations. Furthermore, no significant differences in efficacy have been observed across various diseases. Therefore, the design of this study is based on these industry consensus findings. While we cannot completely exclude the potential impact of cryopreservation versus fresh preparation, the differences between the two methods remain clinically meaningful.

Our logistic regression analysis suggested that treatment frequency was an independent predictor of clinical improvement. Patients who underwent more than three PRP sessions had higher odds of achieving marked improvement compared with those who received fewer sessions. This finding emphasizes the importance of repeated administrations in

sustaining follicular activation. These results align with previous studies, which have consistently shown that PRP's therapeutic benefits are cumulative and require multiple sessions to achieve clinically meaningful improvements.[11–13]

Sex was not found to significantly influence treatment outcomes, suggesting that PRP offers comparable therapeutic benefits to both male and female patients with AGA. Although hormonal influences in AGA pathophysiology might suggest potential sex-specific differences in response to regenerative therapies, our findings show no significant difference in PRP efficacy between male and female patients. Similarly, platelet concentration was not associated with improved efficacy in either group, supporting the idea that platelet counts alone are not the primary factor in PRP effectiveness. Instead, factors such as platelet quality, activation potential, and growth factor functionality likely play more central roles.[14] While the male subgroup shows a significant method effect, this result should be interpreted cautiously due to the potential limitations in statistical power. The small sample size in this subgroup may have contributed to the observed significance, and further studies with larger cohorts are needed to confirm these findings.

Mechanistically, PRP exerts its therapeutic effects through the release of a multitude of growth factors, including PDGF, VEGF, and insulin-like growth factor-1 (IGF-1). These molecules are known to stimulate dermal papilla cell proliferation, enhance angiogenesis, and support hair follicle survival and cycling.[15–17] While higher platelet counts may be assumed to correlate with increased growth factor levels and enhanced efficacy, our findings suggest that this is an oversimplification. The effectiveness of PRP depends not only on platelet concentration but also on activation methods, the freshness of the preparation, and the platelets' ability to release bioactive mediators in a timely and sustained manner. Additionally, leukocytes and plasma proteins in PRP may have paracrine or immunomodulatory effects that could either enhance or interfere with the regenerative process. This complexity may explain why buffy coat PRP, despite its lower platelet yield, achieved similar or better clinical outcomes than apheresis PRP in certain aspects.

These findings have important clinical implications. From a practical standpoint, freshly prepared buffy coat PRP administered over multiple sessions may provide an optimal balance between biological activity, patient tolerability, and treatment outcomes for AGA. Conversely, although apheresis-derived PRP shows superior laboratory indices and may be more suitable for large-volume treatments, its greater procedural complexity and lower patient acceptability may limit its routine clinical use. Clinicians should therefore consider both laboratory efficacy and real-world patient factors when choosing PRP preparation methods for AGA treatment.

This study has several limitations. The retrospective, single-center design and incomplete follow-up may introduce selection bias and limit generalizability. The small sample size, particularly for subgroup analyses, may reduce statistical power. Lack of long-term follow-up and the absence of a non-PRP control group restricts the ability to assess durability and comparative efficacy. Growth factor and platelet function were not measured, and baseline severity staging and concurrent therapies were inconsistently recorded, leaving potential residual confounding. Lastly, apheresis PRP was often cryopreserved and thawed before subsequent injections, while buffy coat PRP was administered fresh, introducing freeze-thaw exposure as a confounder that cannot be fully separated from the preparation method.

Looking forward, future research should focus on prospective randomized controlled trials with larger sample sizes and standardized PRP preparation protocols. Such studies would allow more definitive comparisons between buffy coat and apheresis techniques while minimizing confounding factors. Additionally, mechanistic investigations into platelet viability, growth factor release kinetics, and the role of leukocytes and plasma proteins could provide further insight into the biological mechanisms of PRP efficacy in hair restoration. Finally, emerging approaches such as PRP-derived exosomes, bioengineered platelet products, or combination therapies incorporating stem cells or low-level laser therapy may represent the next step in optimizing regenerative treatments for AGA. These innovations, supported by rigorous clinical evaluation, have the potential to enhance outcomes and establish PRP as a standard treatment for androgenetic alopecia.

Ethics Approval and Consent to Participate

Approval of the research protocol by an Institutional Reviewer Board: This study was reviewed and approved by the Institutional Review Board of The First People's Hospital of Foshan (Approval No.: FSYYY-2025-252). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent for the use of relevant clinical data was obtained from all patients included in this study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This work was supported by funding from the Foshan Municipal Health Bureau (Project No.: 20240068) and the Foshan "14th Five-Year Plan" Key Specialty Project (Project No.:35). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Disclosure

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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