Correlation between Scalp Hair Morphology, Haematological Parameters and Glycaemic Status in Individuals with Diabetes Mellitus

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Abstract

Diabetes mellitus (DM) is a systemic state or condition that affects several physiological and physical features of the human body that includes scalp hair morphology and hair follicles. Present study aimed to study the correlation between scalp hair features, haematological parameters and glycaemic catalogues in diabetic individuals in comparison to healthy controls. The study includes 140 participants, with 70 diabetic individuals and 70 healthy controls. Various parameters such as FBS (fasting blood sugar), PBS (postprandial blood sugar), HbA1c and haematological parameters, were assessed. Histopathological examination of scalp biopsy was done to find out the hair morphology and the anagen-to-telogen proportion, was scientifically assessed. The diabetic individuals showed significant changes in hair characteristics, such as decrease in thickness and tensile strength. Augmented hair loss and disturbed growth phase dispersal were observed, with a lesser percentage of hairs in the anagen phase (60% vs. 80%) and an increased percentage in the telogen phase (28.57% vs. 8.57%).

These modifications reflect the systemic influences of diabetes such as microvascular problems, long-lasting hyperglycaemia and reduced collagen turnover. Significant associations were found among poor glycaemic control, as proved by raised levels of FBS, PBS and HbA1c and hair morphology parameters. Distinguished haematological variations, such as differences in RBC and haemoglobin levels and further inflammatory markers level were also detected in the diabetic group.

Keywords: Hair morphology, Diabetes Mellitus, Parameters.

Introduction

Hair health and its related features are dynamic indicators of systemic wellness that reflected fundamental physiological and pathological conditions. The growth and assembly of hair are predisposed by various factors such as genetics, hormone level, nutritional deficiency and general diseases. Hair growth tails a diverse cycle that comprises of three phases: growth (anagen), regression (catagen) and resting (telogen). The equilibrium among these phases regulates overall hair thickness, width and general quality. Disturbances in this cycle, such as an augmented change over to the telogen phase, can impact in hair diminishing and loss, which repeatedly serves as early markers of systemic disorders[34].

The minute structure of hair, which include its cuticle, cortex and medulla, further provides understandings on hair integrity and flexibility[7]. Scalp hair, as a biomarker, has been broadly studied to recognize its response to hormonal and metabolic changes[20]. Diabetes mellitus, a metabolic disorder featured by chronic hyperglycaemia, employs reflective effects on growth and quality of hair. Its impact is accredited to microvascular problems, reduced circulation and the glycation of functional proteins leading to hair thinning abridged tensile strength and late regrowth[21].

Diabetic individuals frequently display augmented rates of hair detaching and reduced density, which can be sketched back to follicular defective and condensed metabolism[8]. Studies have stated distinguished differences in hair morphology among diabetic and non-diabetic individuals, such as variations in hair thickness, porosity and growth[31]. Additionally, the anagen-to-telogen percentage in diabetic individuals tends to change adversely, highlighting the destructive effects of metabolic instabilities on hair cycling process[16]. Histopathological investigation delivers critical perceptions on the cellular level and structural level alterations in scalp hair and its nearby tissues. In diabetic individuals, the scalp biopsy discloses characteristic modifications like acanthosis, perifollicular fibrosis and diffused fibrosis in dermal layer.

These changes are symptomatic of chronic microvascular injury, condensed collagen turnover and inflammation, all hallmarks of diabetes[33]. The sebaceous glands and other adnexal assemblies also show deteriorating changes, that

reflect in irregular metabolic provision and tissue remodelling in chronic condition[13]. Such histopathological characteristics emphasise the systemic nature of diabetes and its probability to disturb integumental health condition.

Research on hair morphology and follicular healthiness has been done to understand the properties of diabetes on key parameters like stretchable strength, resistance and penetrability. Hair from diabetic individuals frequently illustrates conceded structural veracity, like an injured cuticle and condensed tensile properties, as in indication of oxidative stress and glycation provoked alterations[23].

These remarks are accompanied by dermatoscopic results which afford an exaggerated interpretation of hair shafts and follicles, indicating dissimilar patterns in diabetic individuals[2]. Altogether, these understandings highlight the significance of amalgamating hair analysis into the broader diagnosing and monitoring context for diseases like diabetes, permitting a wide-ranging understanding of its influence on complex human health[6].

Material and Methods

This study was conducted to examine the effect of diabetes on hair morphology and follicular health condition. A total of 140 participants included in the study, consisting of 70 diabetic patients (Cases) and 70 control individuals (non-diabetic). Individuals were recruited from a tertiary care centre with ethical approval from the institutional ethics committee reference number VMKVMC&H/IEC/22/85. Informed consent was obtained from all individuals.

Sample Collection: Scalp hair samples were collected randomly from the different scalp regions of participants. A scalp punch biopsy (4 mm diameter) was performed on selected participants to obtain scalp skin samples containing hair follicles. The biopsy samples were processed for histological examination. Blood samples were collected for biochemical and haematological analysis including fasting blood sugar (FBS), postprandial blood sugar (PBS) and HbA1c levels[35].

Biochemical and Haematological Analysis: FBS and PBS levels were measured using a standard enzymatic glucose oxidase-peroxidase method[22]. HbA1c levels were assessed using analyser (TOSOH) to evaluate long-term glycaemic control[11]. Complete blood count (CBC) and differential counts were performed using an automated CBC analyser to evaluate haematological parameters[26].

Scalp Hair Morphological Analysis: Hair samples were examined macroscopically for thickness, colour, form and texture. Hair thickness was measured using a digital micrometre and tensile strength was assessed with a tensile testing machine[29]. Hair porosity and elasticity were evaluated using standard absorbency and elasticity tests respectively. Hair growth rate was calculated based on participant self-reports of monthly hair length increments[30].

Microscopic Examination: Hair samples were mounted on slides and examined under a light microscope at 10X, 40X and 100X magnifications. Observations focused on cuticle integrity, shaft structure and any visible abnormalities. Scalp hair follicles were examined for density, growth phase distribution (anagen, catagen and telogen phases) and follicular morphology using dermatoscopy[9].

Histopathological Analysis: Scalp biopsy tissues were fixed in 10% neutral buffered formalin, dehydrated and embedded in paraffin. Sections (5 µm) were stained with haematoxylin and eosin (H&E) for microscopic analysis. The slides were examined under light microscope at varying magnifications (10X and 40X) to assess epidermal and dermal changes, perifollicular fibrosis, inflammatory infiltrates and sebaceous gland morphology[13].

Statistical Analysis: Data were analysed and expressed as mean ± standard deviation (SD). Groups were compared by independent t-tests. Categorical variables were analysed using the chi-square test. $p < 0.05$ was set as significance. Hair morphology parameters, such as thickness, density and growth phase distribution, were correlated with glycaemic parameters to assess the impact of diabetes on hair health[27].

Results

Gender Distribution: The gender distribution among the cases and controls showed no significant difference ($p > 0.05$), with 60% of females and 40% of males in both the groups. The total number of participants was 140, with 70 in the diabetic group (cases) and 70 in the control group. The analysis revealed χ^2 value of 0.030 ($p = 0.863$), indicating that gender does not significantly influence the study outcomes.

Fasting Blood Sugar (FBS): As shown in figure 1, diabetics exhibited significantly higher FBS levels than controls ($p < 0.01$), reinforcing FBS as a key diagnostic marker for diabetes. The higher levels of FBS in diabetic participants indicate impaired glucose metabolism. Figure 2 shows that diabetics also show notably higher PBS levels compared to controls ($p < 0.01$), further validating PBS as a strong indicator of diabetes. This suggests that postprandial hyperglycaemia is more pronounced in individuals with diabetes. Figure 3 shows elevated HbA1c levels in diabetic participants ($p < 0.01$) indicating poor long-term glycemic control, confirming HbA1c as an essential marker for diabetes monitoring. The significantly higher HbA1c values in diabetics confirm its role as a crucial marker for monitoring long-term blood glucose levels.

Haematological Parameters: Table 4 indicated significant differences in several haematological parameters between the cases and controls. Diabetic participants had significantly higher RBC count ($p < 0.01$), haemoglobin levels ($p < 0.01$) and WBC count ($p < 0.01$) compared to controls. Additionally, the lymphocyte count was significantly elevated ($p = 0.005$) in the diabetic group.

Table 1
Gender Distribution among Cases and Controls

			Groups		Total	χ 2 - value	p-value
			Cases	Controls			
Gender	Female	Count	42	41	83	0.030	0.863 #
		%	60.0%	58.6%	59.3%		
	Male	Count	28	29	57		
		%	40.0%	41.4%	40.7%		
Total		Count	70	70	140		
		%	100.0%	100.0%	100.0%		
# Statistical Significance is missing at p > 0.05 level							

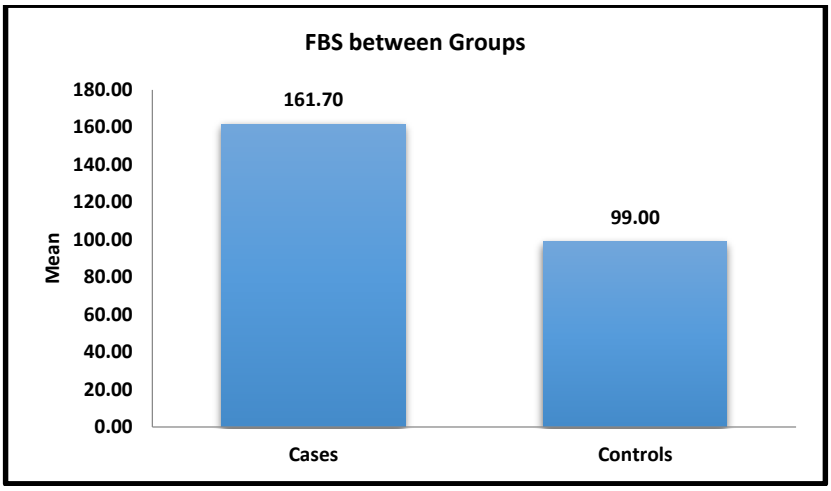

Figure 1: Fasting Blood Sugar levels between Cases and Controls

Table 2
Postprandial Blood Sugar (PBS) analysis in Cases vs. Controls

Variable	Groups	N	Mean	SD	t-value	p-value
PBS	Cases	70	217.70	89.31	9.754	0.0005 **
	Controls	70	112.70	11.64		
** Statistical Significance were experiential at p < 0.01 level						

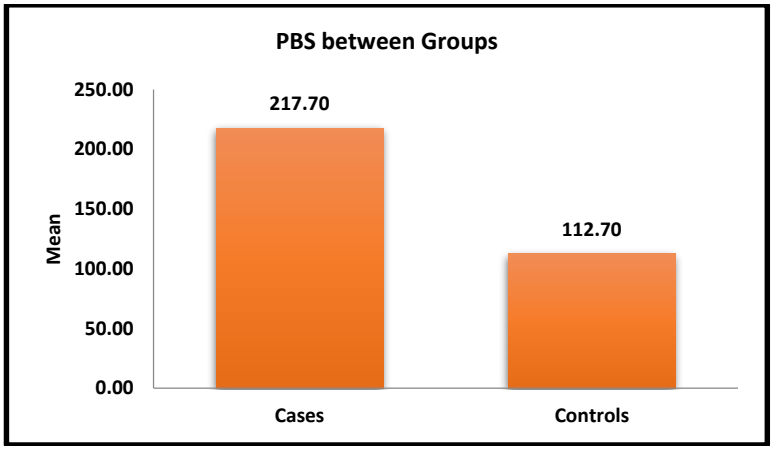

Figure 2: Postprandial Blood Sugar (PBS) levels Between Cases and Controls

Table 3
HbA1c analysis in Cases vs. Controls

Variable	Groups	N	Mean	SD	t-value	p-value
HbA1c	Cases	70	6.79	1.49	7.703	0.0005 **
	Controls	70	5.30	0.62		
** Statistical Significance were extreme at p < 0.01 level						

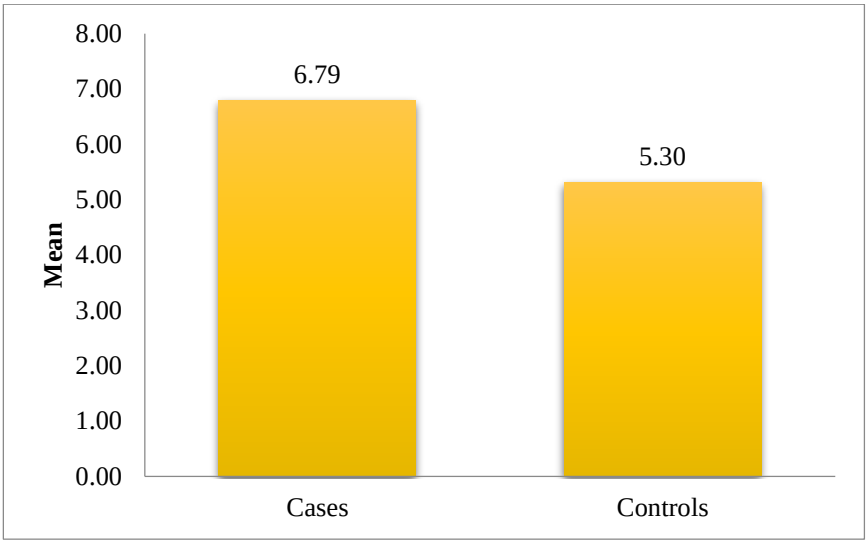

Figure 3: HbA1clevels between Cases and Controls

Table 4
Haematological Parameters in Cases vs. Controls

Variable	Groups	Mean	SD	t-value	p-value
RBC	Cases	4.09	0.42	4.964	0.0005 **
	Controls	3.58	0.76		
Haemoglobin	Cases	11.61	1.51	4.692	0.0005 **
	Controls	9.96	2.53		
MCV	Cases	81.82	9.28	0.525	0.600 #
	Controls	81.00	9.20		
MCH	Cases	28.36	6.92	0.979	0.329 #
	Controls	27.35	5.18		
MCHC	Cases	33.35	1.72	1.000	0.319 #
	Controls	33.66	1.99		
Total WBC Count	Cases	7.48	2.83	4.923	0.0005 **
	Controls	4.41	4.39		
Polymorphs	Cases	61.13	8.09	3.671	0.0005 **
	Controls	66.67	9.70		
Lymphocytes	Cases	34.96	7.98	2.887	0.005 **
	Controls	30.73	9.30		
Eosinophil	Cases	3.80	0.91	6.837	0.0005 **
	Controls	2.66	1.06		
Basophil	Cases	0.32	0.10	5.324	0.0001 **
	Controls	0.41	0.10		
Platelet	Cases	2.38	0.53	0.902	0.369 #
	Controls	2.30	0.54		

Table 5
Monocyte levels in Cases and Controls

			Groups		Total	$\chi 2$ – value	p-value
			Cases	Controls			
Monocytes	1.0	Count	23	7	30	1.458	0.227 #
		%	82.1%	100.0%	85.7%		
	2.0	Count	5	0	5		
		%	17.9%	0.0%	14.3%		
Total		Count	28	7	35		
		%	100.0%	100.0%	100.0%		
Significance were not found at p > 0.05 level							

However, parameters like MCV, MCH, MCHC and platelet count did not show significant differences between the two groups ($p > 0.05$). Table 5 shows no significant difference in monocyte levels between groups ($p > 0.05$), suggesting that monocyte counts are not majorly affected by diabetes in this cohort. Table 6 showed no significant difference in platelet count between the cases and controls ($p > 0.05$), indicating that platelet levels remain relatively stable in diabetes within this population.

Hair Morphology: Diabetics group exhibited noticeable variations in hair morphology including lower hair thickness, reduced hair growth rate and diminished tensile strength compared to controls. These changes may be attributed to microvascular complications that affect hair health, possibly reducing nutrient supply to hair follicles.

Hair Thickness and Density: Hair thickness was significantly reduced in the diabetic group ($p < 0.01$), with an average thickness of 67.99 mm compared to 77.67 mm in controls. Additionally, a significant decrease in hair density in diabetics ($p < 0.01$) suggests that diabetes may impair hair volume, likely due to poor circulation or nutrient delivery.

Hair Loss: Diabetic group experienced significantly more hair loss ($p < 0.01$) compared to controls. This increased hair loss is likely due to metabolic stress and compromised follicular health in diabetics. Table 7 shows diabetics have a lower proportion of anagen (growth) phase hairs and a higher proportion in the telogen (resting) phase, indicating disrupted hair growth cycles likely due to diabetic complications. Diabetic group had a lower proportion of anagen phase hairs (60%) compared to controls (80%) and a higher proportion of telogen phase hairs (28.57% in diabetics versus 8.57% in controls). This altered hair growth cycle, characterized by a reduced anagen-to-telogen ratio in diabetics, suggesting that diabetes disrupts the hair growth cycle, possibly due to complications related to the disease.

Histopathological Analysis: Histopathological examination of scalp hair follicles revealed significant alterations in the diabetic group (Figure 5) compared to controls (Figure 4). In the diabetic group (Figure 5), the epidermis showed acanthosis (thickening), which may be linked to insulin resistance or chronic hyperglycaemia. The dermis exhibited diffuse fibrosis, indicative of diabetes-induced microvascular damage and impaired tissue remodelling.

Additionally, perifollicular fibrosis and degenerative changes in the hair follicles were observed, possibly due to microangiopathy and reduced metabolic support to the follicles. Mild inflammatory infiltrates were noted, reflecting the chronic low-grade inflammation associated with diabetes. These histopathological changes further support the impact of diabetes on hair follicle health and structure. Overall, the results suggest that diabetes leads to significant alterations in hair morphology, growth cycles and follicular health, potentially due to impaired circulation, microvascular complications and metabolic disturbances.

Discussion

The hematological parameters analyzed in the present study include red blood cells (RBC), hemoglobin (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), total white blood cell (WBC) count, differential counts (polymorphs, lymphocytes, eosinophils, monocyte and basophils) and platelets. All parameters had demonstrated significant associations with diabetes and hair morphology.

Table 6
Platelet count analysis in Cases vs. Controls

Variable	Groups	N	Mean	SD	t-value	p-value
Platelet	Cases	70	2.38	0.53	0.902	0.369 #
	Controls	70	2.30	0.54		
Significance not found at $p > 0.05$ level						

Table 7
Hair Growth Phase Distribution in Relation to Diabetes

Parameter	Cases	Control
Total Patients (N)	70	70
Anagen Hairs (Mean)	42 (60%)	56 (80%)
Catagen Hairs (Mean)	8 (11.43%)	8 (11.43%)
Telogen Hairs (Mean)	20 (28.57%)	6 (8.57%)
Anagen to Telogen Ratio	6:1	14:1
Percentage of Hairs in Anagen	60%	80%
Percentage of Hairs in Catagen	11.43%	11.43%
Percentage of Hairs in Telogen	28.57%	8.57%

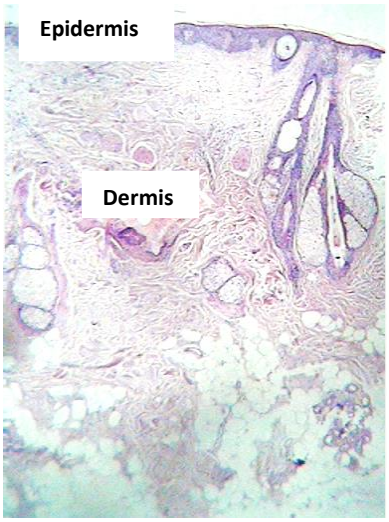

Figure 4a: Scalp Biopsy Tissue (H&E)×10

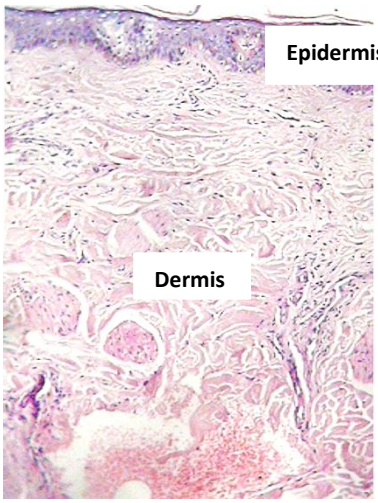

Figure 4b: Scalp Biopsy Tissue (H&E)×40

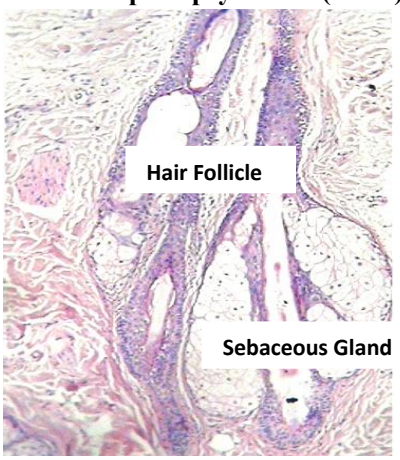

Figure 4c: Hair follicles and sebaceous glands (H&E)×10

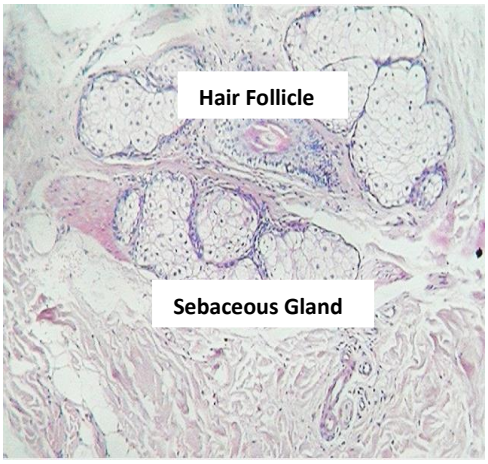

Figure 4d: Hair follicles and sebaceous glands (H&E)×40

Figure 4: Histopathological Analysis of Scalp Hair Follicles in Control Group

Correlation of these parameters with the underlying pathophysiological mechanisms in diabetes with hair-related disorders was analysed and compared to the earlier studies.

RBC and Hemoglobin Levels: A significant reduction in RBC count and hemoglobin levels was observed in diabetic patients (cases) compared to controls ($p < 0.001$). The present findings go in hand with previous studies that have linked diabetes with anemia, a common comorbidity due to various factors such as renal dysfunction, chronic inflammation and altered erythropoiesis[1].

The reduction in RBC and Hb may impair oxygen delivery to tissues, which can, in turn, impact hair follicle health and contribute to hair thinning or hair loss seen in diabetic patients. The relationship between anemic states and hair loss is well-documented, with studies suggesting that anemia can lead to telogen effluvium, a condition where hair follicles prematurely enter the shedding phase[3].

MCV, MCH and MCHC: The values for MCV, MCH and MCHC were not significant differences in between the groups, suggesting that these indices were not significantly altered by the presence of diabetes in the cohort studied. However, minor variations could still be of clinical relevance, particularly in patients with diabetic neuropathy or those on medications affecting red blood cell production. The lack of significant change in MCV, MCH and MCHC is also in line with findings from studies exploring the lack of a direct link between these indices and hair morphology[25].

WBC Count and Differential Leukocyte Count: Total WBC count and the differential counts of polymorphs, lymphocytes, eosinophils and basophils were notably higher in diabetic cases, indicating a systemic inflammatory response often seen in individuals with uncontrolled diabetes ($p < 0.001$). Elevated WBC count, particularly polymorphonuclear neutrophils, may reflect the chronic inflammatory state that is characteristic of diabetes. This chronic low-grade inflammation is linked to hair loss, particularly androgenic alopecia[5].

The relationship between inflammatory mediators and hair loss suggests that higher WBC counts and an altered immune profile may exacerbate or even trigger autoimmune-mediated hair conditions such as alopecia areata.

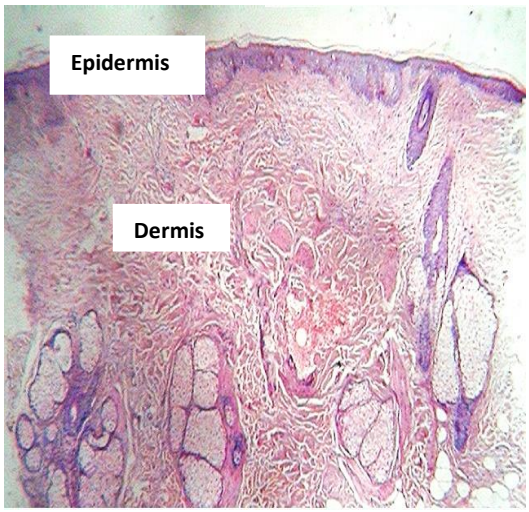

Figure 5a: Scalp Biopsy Tissue (H&E)×10

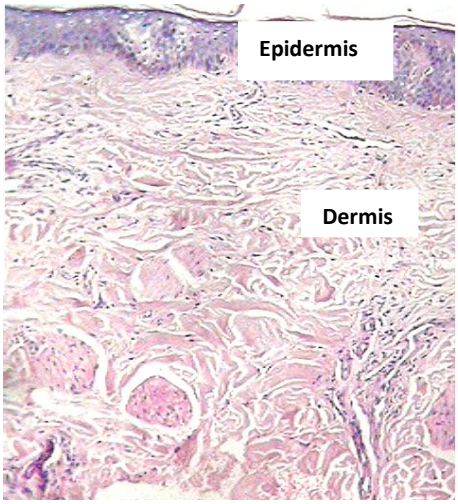

Figure 5b: Scalp Biopsy Tissue (H&E)×40

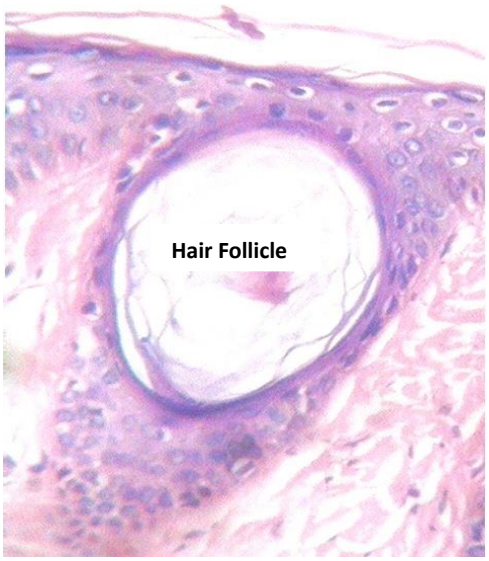

Figure 5c: Hair follicles and sebaceous glands (H&E)×10

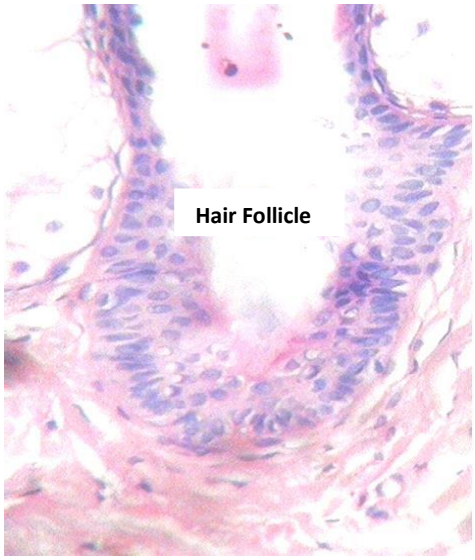

Figure 5d: Hair follicles showing perifollicular fibrosis (H&E)×40

Figure 5: Histopathological Analysis of Scalp Hair Follicles in Diabetic Group

Eosinophils and basophils were significantly elevated in the diabetic group, pointing towards an allergic or hypersensitivity response commonly observed in individuals with metabolic disturbances[28]. These elevated eosinophil and basophil levels may also be indicative of an underlying allergic dermatitis or inflammatory scalp condition that can further aggravate hair loss. In the context of hair morphology, such conditions could influence the hair cycle, leading to an increased incidence of shedding or a decrease in the anagen (growth) phase of the hair follicles.

Platelet Count: Interestingly, platelet counts did not show significant differences between the groups, which may reflect the absence of significant clotting or vascular changes in this cohort. However, the role of platelets in hair follicle regeneration and wound healing, particularly in diabetic patients, has to be focussed. There is growing evidence that platelet-derived growth factors (PDGFs) play a role in the hair growth cycle and platelet dysfunction in diabetes could potentially affect hair follicle function[5]. This present study highlights the complex interplay between hematological parameters, diabetes and hair morphology. Elevated inflammatory markers, anemia and changes in immune cell subsets may collectively contribute to hair loss in diabetic individuals, possibly through mechanisms of tissue hypoxia, chronic inflammation and altered immune responses. Future research should focus on longitudinal studies to examine how these hematological alterations correlate with hair regeneration processes in diabetic patients and whether interventions targeting these parameters could help to mitigate hair loss in this population.

Scalp Hair Morphology: The findings from this study highlight significant changes in hair morphology, growth phases and histopathological characteristics in diabetic participants, underscoring the profound effects of diabetes on scalp hair health. Diabetic individuals exhibited thinner hair, reduced hair density and a higher incidence of hair loss compared to healthy controls. This is consistent with existing literature that has reported hair thinning and hair

loss as common manifestations in individuals with diabetes, often attributed to microvascular damage, metabolic imbalances and hormonal alterations[18,32]. The reduced hair thickness and density in the diabetic group may be a result of impaired circulation and nutrient delivery to hair follicles, exacerbated by the effects of hyperglycaemia on vascular health, as diabetes is known to induce microangiopathy[19]. Additionally, the observed differences in hair growth rates and tensile strength further emphasize the negative impact of diabetes on the hair follicle's ability to sustain healthy growth[4].

Hair Growth Cycle: The hair growth cycle analysis revealed that diabetics had a lower percentage of hairs in the anagen phase (growth phase) and a higher percentage in the telogen phase (resting phase) when compared to controls. This altered distribution of hair in various growth phases is indicative of disrupted hair follicle cycles, a phenomenon frequently observed in other systemic disorders including diabetes[36]. The lower anagen-to-telogen ratio observed in diabetic individuals suggests impairment in the transition from the growth phase to the resting phase, likely due to systemic metabolic disruptions and hormonal imbalances associated with diabetes[10].

Histopathological analysis further revealed structural alterations in hair follicles and surrounding tissues in the diabetic group including perifollicular fibrosis and reduced sebaceous gland activity. The presence of fibrosis and changes in the extracellular matrix within the dermal layer is indicative of diabetes-induced microvascular damage, which compromises tissue remodelling and nutrient exchange, potentially affecting the health and function of hair follicles[12]. The fibrosis surrounding the hair follicles and the observed acanthosis of the epidermis align with findings in previous studies that describe the detrimental effects of chronic hyperglycaemia on skin and hair follicle health[24].

These findings emphasize the critical role of managing diabetes in preventing hair-related complications, as the systemic effects of uncontrolled blood sugar levels can severely impact hair growth, quality and overall scalp health. The altered histopathological characteristics observed in the diabetic group including fibrosis and reduced follicular prominence, underscore the need for early intervention to mitigate the long-term consequences of diabetes on dermatological health. Moreover, these findings highlight the importance of monitoring hair health as part of a broader clinical strategy in managing diabetic patients, potentially serving as an early indicator of the systemic complications associated with diabetes.

Conclusion

Diabetes significantly affects scalp hair health, resulting in thinner hair, reduced density and increased hair loss. Impaired circulation, nutrient delivery and microangiopathy contribute to these changes in hair morphology. Diabetic individuals exhibit a disrupted hair growth cycle, with lower anagen and higher telogen phase percentages. The altered anagen-to-telogen ratio indicates impaired transition from the growth to the resting phase of the hair cycle. Histopathological analysis reveals fibrosis, reduced sebaceous gland activity and structural changes in hair follicles due to microvascular damage.

Chronic hyperglycaemia leads to significant damage to skin and hair follicles, emphasizing the importance of blood sugar control. Early intervention and regular monitoring of hair health in diabetic patients are crucial for preventing long-term dermatological complications.

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