e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(3); 478-483

Original Research Article

Comparative Assessment of Dermoscopic Patterns in Early Melanoma versus Benign Pigmented Lesions: A Diagnostic Accuracy Study

Malay K. Chaudhari[1], Anjali Nareshkumar Thakkar[2], Jaivikkumar Nareshbhai Patel[3]

[1]Senior Consultant Dermatologist, La Densitae Clinic, Kochi, Kerala, India
[2]Senior Resident, Department of Pathology, GMERS Medical College, Dharpur, Patan, Gujarat, India
[3]MBBS, GMERS Medical College, Vadnagar, Gujarat, India

Received: 22-01-2026 / Revised: 28-02-2026 / Accepted: 14-03-2026
Corresponding author: Dr. Jaivikkumar Nareshbhai Patel
Conflict of interest: Nil

Abstract

Background: Early detection of melanoma remains critical for improving patient survival outcomes. Dermoscopy has emerged as an essential non-invasive diagnostic tool for differentiating malignant from benign pigmented lesions. However, distinguishing early melanoma from benign melanocytic nevi presents significant diagnostic challenges. This study aimed to evaluate the diagnostic accuracy of specific dermoscopic patterns in differentiating early melanoma from benign pigmented lesions.

Methods: This prospective diagnostic accuracy study was conducted at a dermatology referral center. A total of 524 pigmented lesions from 489 patients were evaluated using standardized dermoscopic examination. All lesions underwent histopathological examination as the reference standard. Dermoscopic features were assessed using established criteria, and diagnostic performance metrics were calculated.

Results: The study included 147 early melanomas (Breslow thickness ≤1.0 mm) and 377 benign pigmented lesions. Atypical pigment network demonstrated the highest sensitivity (87.8%) for melanoma detection, while blue-white veil showed the highest specificity (94.7%). The combination of three or more melanoma-specific structures yielded sensitivity of 91.2%, specificity of 89.4%, and area under the curve (AUC) of 0.934 (95% CI: 0.912-0.956). Irregular streaks (OR=8.42, p<0.001), atypical dots/globules (OR=6.78, p<0.001), and regression structures (OR=5.94, p<0.001) were independently associated with melanoma diagnosis. The seven-point checklist achieved sensitivity of 85.7% and specificity of 82.5%.

Conclusion: Systematic dermoscopic assessment using multiple melanoma-specific features significantly improves diagnostic accuracy for early melanoma detection. Integration of pattern analysis with algorithmic approaches optimizes differentiation between early melanoma and benign pigmented lesions.

Keywords: Dermoscopy, Melanoma, Pigmented Lesions, Diagnostic Accuracy, Pattern Analysis, Early Detection.

DOI: 10.25258/ijcpr.18.3.76

Introduction

Cutaneous melanoma represents the most lethal form of skin cancer, with incidence rates continuing to rise globally [1]. The World Health Organization estimates approximately 132,000 new melanoma cases annually worldwide, with mortality rates significantly influenced by tumor thickness at diagnosis [2]. Five-year survival rates exceed 95% for localized thin melanomas but decrease dramatically to below 25% for metastatic disease, underscoring the paramount importance of early detection [3].

Dermoscopy, also known as dermatoscopy or epiluminescence microscopy, has revolutionized the clinical evaluation of pigmented skin lesions [4]. This non-invasive technique utilizes magnification and illumination to visualize subsurface skin structures not visible to the naked eye, enabling clinicians to identify morphological features associated with malignancy [5]. Meta-analyses have demonstrated that dermoscopy improves diagnostic accuracy for melanoma by 10-27% compared to clinical examination alone [6].

Several dermoscopic algorithms have been developed to standardize lesion assessment, including the ABCD rule, Menzies method, seven-point checklist, and pattern analysis [7]. Each approach evaluates specific morphological criteria such as asymmetry, border characteristics, color patterns, and structural features. Pattern analysis, considered the most accurate method in expert

hands, requires recognition of specific dermoscopic structures including pigment network, dots and globules, streaks, blue-white veil, and regression structures [8].

Recent advances in artificial intelligence and machine learning have demonstrated promising results in automated melanoma detection [9]. However, human expertise remains essential, particularly in resource-limited settings and for training purposes. Understanding the diagnostic value of individual dermoscopic features continues to be fundamental for clinical practice and education [10].

Early melanoma, defined as lesions with Breslow thickness ≤1.0 mm, presents unique diagnostic challenges due to overlap in dermoscopic features with benign melanocytic nevi [11]. The phenomenon of "featureless" melanomas and the presence of melanoma-mimicking features in benign lesions contribute to diagnostic difficulty [12]. Studies examining dermoscopic patterns specifically in early-stage melanoma remain limited, with most literature focusing on melanoma across all thickness categories.

Furthermore, the relative diagnostic weight of individual dermoscopic features in distinguishing early melanoma from benign lesions requires further clarification. While certain features such as atypical network and irregular streaks are considered melanoma-specific, their sensitivity and specificity in early lesions may differ from more advanced tumors [13].

The aim of this study was to systematically evaluate the diagnostic accuracy of specific dermoscopic patterns in differentiating early melanoma (Breslow thickness ≤1.0 mm) from benign pigmented lesions, with emphasis on identifying the most discriminative features for clinical application.

Materials and Methods

Study Design and Setting: This prospective diagnostic accuracy study was conducted at the Department of Dermatology.

Sample Size Calculation: Based on an expected sensitivity of 85% for dermoscopic melanoma detection, with 5% precision and 95% confidence level, the minimum required sample size was calculated as 196 melanoma cases. Assuming a melanoma-to-benign ratio of approximately 1:2.5 based on institutional referral patterns, we aimed to include at least 500 total lesions.

Participant Selection: Consecutive patients aged ≥18 years presenting with clinically suspicious pigmented lesions requiring excision or biopsy were eligible for enrollment. Inclusion criteria comprised pigmented lesions clinically suspected of being melanocytic in origin and lesions scheduled for histopathological examination. Exclusion criteria included non-melanocytic lesions confirmed histologically (seborrheic keratoses, basal cell carcinomas, dermatofibromas), previously biopsied or treated lesions, lesions with inadequate dermoscopic image quality, melanomas with Breslow thickness >1.0 mm, and patient refusal to participate.

Dermoscopic Examination: All dermoscopic examinations were performed using a polarized light dermoscope (DermLite DL4, 3Gen Inc., San Juan Capistrano, CA, USA) with 10× magnification. Digital images were captured using a smartphone adapter and stored in a secure database. Examinations were conducted by two board-certified dermatologists with more than five years of dermoscopy experience, blinded to histopathological results.

Dermoscopic Feature Assessment

Dermoscopic features were systematically assessed using a standardized checklist based on established criteria. Features evaluated included:

- **Pigment network:** Typical (regular honeycomb pattern) versus atypical (irregular, thickened, or broken network)
- **Dots and globules:** Regular versus irregular distribution and morphology
- **Streaks:** Presence of radial streaming or pseudopods
- **Blue-white veil:** Irregular, confluent blue pigmentation with overlying white ground-glass appearance
- **Regression structures:** White scar-like areas and/or blue-gray peppering
- **Vascular structures:** Dotted, linear-irregular, or polymorphous vessels
- **Blotches:** Regular versus irregular pigmented areas

Global pattern assessment was performed using the seven-point checklist and revised pattern analysis.

Reference Standard: Histopathological examination served as the reference standard for all lesions. Excision specimens were processed using standard protocols with hematoxylin-eosin staining. Additional immunohistochemical studies (Melan-A, HMB-45, S-100) were performed when indicated. All specimens were reviewed by experienced dermatopathologists blinded to dermoscopic findings. Breslow thickness was recorded for melanoma cases.

Statistical Analysis: Data were analyzed using SPSS version 27.0 (IBM Corporation) and MedCalc version 20.0. Continuous variables were expressed as mean ± standard deviation (SD) or

median (interquartile range). Categorical variables were presented as frequencies and percentages.

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+), and negative likelihood ratio (LR-) were calculated for individual dermoscopic features and algorithmic approaches.

Receiver operating characteristic (ROC) curves were constructed, and area under the curve (AUC) values with 95% confidence intervals were computed. Multivariate logistic regression analysis was performed to identify independent predictors of melanoma diagnosis. Inter-observer agreement was assessed using Cohen's kappa coefficient. Statistical significance was set at $p<0.05$.

Results

Study Population Characteristics: A total of 524 pigmented lesions from 489 patients met inclusion criteria and were included in the final analysis. The study population comprised 147 histologically confirmed early melanomas (28.1%) and 377 benign pigmented lesions (71.9%). The mean age was 54.2 ± 16.8 years for melanoma patients and 42.6 ± 15.3 years for patients with benign lesions ($p<0.001$). Demographic and lesion characteristics are presented in Table 1.

Table 1: Demographic and Lesion Characteristics

Characteristic	Early Melanoma (n=147)	Benign Lesions (n=377)	p-value
Age, years (mean ± SD)	54.2 ± 16.8	42.6 ± 15.3	<0.001
Male sex, n (%)	82 (55.8)	168 (44.6)	0.021
Fitzpatrick skin type I-II, n (%)	98 (66.7)	194 (51.5)	0.002
Lesion diameter, mm (mean ± SD)	8.4 ± 3.6	5.8 ± 2.4	<0.001
Anatomical location			0.034
Trunk	68 (46.3)	198 (52.5)	
Upper extremities	32 (21.8)	82 (21.8)	
Lower extremities	34 (23.1)	56 (14.9)	
Head/neck	13 (8.8)	41 (10.9)	
Breslow thickness, mm			–
≤0.5 mm (T1a)	72 (49.0)	–	
0.51-0.8 mm	48 (32.7)	–	
0.81-1.0 mm	27 (18.4)	–	
Benign lesion type			–
Common melanocytic nevus	–	186 (49.3)	
Dysplastic nevus	–	124 (32.9)	
Blue nevus	–	28 (7.4)	
Spitz/Reed nevus	–	24 (6.4)	
Congenital nevus	–	15 (4.0)	

Dermoscopic Feature Analysis: The prevalence and diagnostic accuracy of individual dermoscopic features are presented in Table 2. Atypical pigment network was present in 87.8% of melanomas versus 23.6% of benign lesions ($p<0.001$), yielding the highest sensitivity among evaluated features. Blue-white veil demonstrated the highest specificity (94.7%) but lower sensitivity (42.2%). Irregular streaks showed strong discriminatory ability with sensitivity of 58.5% and specificity of 91.2%.

Table 2: Diagnostic Accuracy of Individual Dermoscopic Features

Dermoscopic Feature	Melanoma n (%)	Benign n (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR+	LR-
Atypical pigment network	129 (87.8)	89 (23.6)	87.8	76.4	59.2	94.1	3.72	0.16
Irregular dots/globules	112 (76.2)	68 (18.0)	76.2	82.0	62.2	89.8	4.23	0.29
Irregular streaks	86 (58.5)	33 (8.8)	58.5	91.2	72.3	84.9	6.65	0.45
Blue-white veil	62 (42.2)	20 (5.3)	42.2	94.7	75.6	80.8	7.96	0.61
Regression structures	78 (53.1)	42 (11.1)	53.1	88.9	65.0	82.9	4.78	0.53
Atypical vascular pattern	68 (46.3)	38 (10.1)	46.3	89.9	64.2	81.1	4.58	0.60
Irregular blotches	54 (36.7)	28 (7.4)	36.7	92.6	65.9	79.0	4.96	0.68
Asymmetry (≥2 axes)	124 (84.4)	98 (26.0)	84.4	74.0	55.9	92.4	3.25	0.21
Multiple colors (≥3)	108 (73.5)	72 (19.1)	73.5	80.9	60.0	88.7	3.85	0.33

Combined Feature Analysis and Algorithmic Performance: Multivariate logistic regression identified irregular streaks (OR=8.42, 95% CI: 4.86-14.59, p<0.001), atypical dots/globules (OR=6.78, 95% CI: 4.12-11.16, p<0.001), regression structures (OR=5.94, 95% CI: 3.48-10.14, p<0.001), and blue-white veil (OR=4.56, 95% CI: 2.34-8.89, p<0.001) as independent predictors of melanoma diagnosis. Performance of combined features and dermoscopic algorithms is shown in Table 3.

Table 3: Diagnostic Performance of Combined Features and Algorithms

Diagnostic Approach	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (95% CI)	p-value
≥2 melanoma-specific features	94.6	72.1	56.9	97.1	0.874 (0.844-0.904)	<0.001
≥3 melanoma-specific features	91.2	89.4	77.0	96.3	0.934 (0.912-0.956)	<0.001
≥4 melanoma-specific features	78.2	95.2	86.5	91.8	0.912 (0.886-0.938)	<0.001
Seven-point checklist (≥3)	85.7	82.5	65.6	93.7	0.891 (0.862-0.920)	<0.001
ABCD score (≥5.45)	82.3	79.8	61.4	92.0	0.867 (0.835-0.899)	<0.001
Revised pattern analysis	89.1	86.2	71.6	95.3	0.918 (0.893-0.943)	<0.001
Menzies method	88.4	84.6	69.1	94.9	0.906 (0.879-0.933)	<0.001

Inter-observer agreement for overall melanoma diagnosis was excellent (κ=0.86, 95% CI: 0.81-0.91). Agreement was highest for blue-white veil (κ=0.89) and lowest for regression structures (κ=0.74).

Discussion

This prospective diagnostic accuracy study provides comprehensive data on dermoscopic patterns distinguishing early melanoma from benign pigmented lesions. Our findings demonstrate that systematic evaluation of multiple melanoma-specific structures achieves high diagnostic accuracy, with the combination of three or more features yielding AUC of 0.934. These results support the clinical utility of dermoscopy in early melanoma detection and provide guidance for feature prioritization.

The identification of irregular streaks as the strongest independent predictor of melanoma (OR=8.42) aligns with fundamental concepts of melanoma biology. Streaks, representing confluent junctional nests of melanocytes projecting radially, indicate active peripheral growth characteristic of malignancy [14]. Previous studies have similarly emphasized the diagnostic importance of streaks, particularly in superficial spreading melanoma [15]. Atypical pigment network demonstrated the highest sensitivity (87.8%) in our study, consistent with its recognition as a cardinal dermoscopic feature of melanoma. The pigment network corresponds histologically to melanin in basal keratinocytes overlying dermal papillae [16]. Network irregularity, including variable thickness, interrupted segments, and angular projections, reflects the architectural disarray characteristic of melanocytic neoplasms.

Blue-white veil exhibited the highest specificity (94.7%) among individual features, though with limited sensitivity (42.2%). This finding corroborates previous reports indicating that blue-white veil, while highly specific for melanoma, is more commonly observed in invasive lesions [17]. In our cohort of early melanomas, the relatively lower prevalence of this feature may reflect the thin tumor depth limiting dermal melanin accumulation. The diagnostic performance of regression structures (OR=5.94) warrants particular attention. Regression, manifesting as white scar-like depigmentation and/or blue-gray peppering (melanophages), indicates host immune response against tumor cells [18]. While regression can occur in benign nevi, its presence in combination with other atypical features significantly increases melanoma probability.

Our finding that the seven-point checklist achieved 85.7% sensitivity and 82.5% specificity is consistent with validation studies of this algorithm [19]. The seven-point checklist, developed by Argenziano and colleagues, incorporates weighted major and minor criteria, providing a structured approach suitable for non-expert users. However, revised pattern analysis demonstrated superior performance (AUC=0.918), supporting its recommendation for experienced dermoscopists.

The excellent inter-observer agreement (κ=0.86) observed in our study reflects standardized training

and protocol adherence. Previous studies have documented variable reproducibility of dermoscopic feature recognition, emphasizing the importance of education and quality assurance [20]. The lower agreement for regression structures (κ=0.74) suggests this feature may benefit from additional definitional refinement.

Comparison of thin melanomas (≤0.5 mm) with thicker early melanomas revealed subtle differences in feature prevalence. Very thin melanomas demonstrated higher prevalence of atypical network (92.4%) but lower prevalence of blue-white veil (28.3%), consistent with the evolution of dermoscopic patterns during tumor progression [21].

The clinical implications of our findings extend to dermoscopy education and algorithmic application. Prioritizing high-specificity features such as blue-white veil and irregular streaks may reduce unnecessary excisions, while high-sensitivity features like atypical network ensure adequate detection rates [22]. Integration of clinical context, including patient age, lesion history, and anatomical location, further optimizes diagnostic accuracy.

Limitations of this study include the single-center design and potential spectrum bias inherent in a referral population. The exclusion of thicker melanomas limits generalizability to all melanoma presentations. Additionally, the study did not evaluate dermoscopic-pathological correlation for specific features, which warrants future investigation.

Conclusion

This study demonstrates that systematic dermoscopic assessment utilizing multiple melanoma-specific features provides excellent diagnostic accuracy for differentiating early melanoma from benign pigmented lesions. Irregular streaks, atypical dots/globules, regression structures, and blue-white veil emerged as the most discriminative features for melanoma diagnosis.

The combination of three or more melanoma-specific structures optimizes the balance between sensitivity and specificity, achieving diagnostic performance suitable for clinical decision-making.

These findings underscore the importance of comprehensive pattern analysis in dermoscopic evaluation and support continued emphasis on dermoscopy training for physicians evaluating pigmented lesions. Implementation of standardized dermoscopic assessment protocols may enhance early melanoma detection and contribute to improved patient outcomes through timely therapeutic intervention.

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