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Original Article

Histopathological Differences Between Atrophic and Progressive Primary Pterygium: A Clinicopathological Correlation Study

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Abstract

Objective: To Compare the Histopathological Features of Atrophic and Progressive Primary Pterygium.

Methodology: This Correlational study was conducted in the Department of Anatomy, Rawalpindi Medical University, Rawalpindi, Pakistan, from January 2020 to January 2021. We collected clinical data and pterygium specimens. Out of 41 primary pterygium specimens, 31 were clinically atrophic, and 10 were progressive. We processed excised tissue for light microscopy. Histological assessment included basement membrane fragmentation and delayering, epithelial separation, epithelial fragmentation, epithelial invagination, goblet-cell pattern, stromal inflammatory infiltration, and elastosis. We used Fisher's exact test for binary findings and the Mann-Whitney U test for ordinal histological grades. We considered p-values below 0.05 significant.

Results: Basement membrane fragmentation was present in 93.5% of atrophic and 100% of progressive lesions. Basement membrane delayering was present in 80.6% of atrophic lesions and 80.0% of progressive lesions. Epithelial fragmentation was found in 90.3% of atrophic and all progressive lesions, while epithelial invagination was seen in 96.8% of atrophic and 80.0% of progressive lesions. Diffuse inflammatory infiltration was present in about 90% of both groups. High-grade elastosis (>10%) was present in 77.4% of atrophic and 80.0% of progressive lesions. No statistically significant differences were detected for the measured histopathological features.

Conclusion: Atrophic and progressive pterygia demonstrated broadly similar histopathological features, with no significant differences between groups. These findings suggest that clinical classification alone may not reflect underlying tissue changes. Quantitative histomorphometric assessment may improve clinicopathological correlation and disease characterization.

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Introduction

Pterygium is a common ocular surface disease characterized by a triangular or wing-shaped fibrovascular growth of conjunctival tissue that extends across the limbus onto the cornea. It is especially common in people exposed to ultraviolet (UV) radiation, heat, dust, wind, and other environmental irritants for long periods. UV exposure is believed to be the dominant risk factor. However, available data suggest that a complex interplay of environmental, cellular, inflammatory, and molecular processes drives pterygium development, rather than a single risk factor [1]. Continuous exposure to UV radiation, especially UV-B, can induce oxidative stress, damage the genome of limbal epithelial cells, and impair normal function in limbal stem cells. These changes can promote abnormal growth and migration of altered cells toward the cornea. This cellular damage brought on by UV also triggers inflammatory responses and results in the release of cytokines, growth factors and other mediators that promote tissue repair and proliferation [2,3]. Inflammation plays an important part in the development and progression of pterygium. Environmental irritation may lead to the release of inflammatory mediators and stimulate activation of stromal fibroblasts in the conjunctiva. Increased expression of vascular endothelial growth factor (VEGF) and other angiogenic factors drives new blood vessel formation, giving the lesion its characteristic fibrovascular appearance. Meanwhile, matrix metalloproteinases (MMPs) and other enzymes remodel and degrade the extracellular matrix, allowing pterygium to spread over the cornea and disrupt Bowman's layer [4]. Recent molecular research also highlights roles for oxidative stress, altered cell-cycle regulation and apoptosis control, tumor-suppressor pathways, the E-M transition, and ECM abnormalities. Pterygium is now seen as an ocular surface disease rather than a degenerative disease. It is more of a multifactorial ocular surface disorder that combines proliferative and inflammatory processes [5,6].

Materials and Methods

Material And Methods

this is a cross-sectional analytical clinicopathological study. clinical data and pterygium specimens were collected. the patients were 25-70 years of age, and only those for whom pterygium surgery had already been decided were included. informed consent was obtained before clinical examination and collection of the excised tissue for research. the clinical examination and classification of the pterygium as atrophic or progressive were completed before surgery. the present manuscript did not recruit a new group of patients or collect new specimens; it retrospectively analyzed the existing clinical and histopathological data from the parent research project. therefore, the parent research project was prospective in data and specimen collection, whereas the present manuscript is a retrospective secondary analysis of those prospectively collected cross-sectional data and specimens. the parent research project also included age- and sex-matched healthy controls, but the present analysis included only the 41 patients with excised primary pterygium specimens because pterygium tissue was not available from the healthy controls. of the 41 lesions, 31 were recorded as atrophic and 10 as progressive. study period: the overall study period was from january

2020 to january 2021. patient recruitment, preoperative clinical data collection and pterygium specimen collection were carried out from january 2020 to october 2020.

sample-size

41 primary pterygium specimens were available from the parent research project. the final groups consisted of 31 atrophic and 10 progressive lesions, reflecting the clinical distribution in the parent dataset rather than a planned equal allocation. because the progressive group was small and the groups were unequal, the study had limited ability to detect small or moderate differences between the two groups. therefore, non-significant findings should be interpreted cautiously and should not be taken as evidence that the two clinical groups are equivalent.

clinical examination and classification

before surgery, a complete eye examination was performed, and the pterygium was assessed for the eye involved, presence or absence of inflammation, size, site, and type, as well as stocker's line and fuchs' spot. we recorded pterygium size as type 1 when it was less than 2 mm, type 2 when it was up to 4 mm, and type 3 when it extended to the pupillary margin or involved the visual axis. the lesions were recorded clinically as atrophic or progressive before surgery. slit-lamp examination was used to assess the thickness, translucency, fleshiness, and visibility of the underlying episcleral vessels. we defined an atrophic pterygium as a thin, pale, relatively translucent lesion in which the underlying episcleral vessels were clearly visible. a progressive pterygium was defined as a thick, fleshy, vascular and relatively opaque lesion in which the underlying episcleral vessels were partially or completely obscured. the clinical classification was completed before surgical excision.

Tissue Processing

the excised pterygium tissue was received in 10% buffered formalin and allowed to fix for about 48 hours. each specimen was placed in a properly labeled tissue cassette and processed using an automated tissue processor. the tissue was dehydrated through ascending grades of alcohol, cleared in xylene, infiltrated, and embedded in paraffin wax. sections approximately 3-5 micrometers thick were cut on a microtome, placed in a water bath at about 45°C, and mounted on labeled slides. hematoxylin and eosin staining was used to assess general epithelial and stromal morphology and inflammatory cells. periodic acid-schiff-haematoxylin staining was used mainly to assess the basement membrane and goblet-cell morphology, while verhoeff staining was used

to assess elastic fibers. histopathological examiner and blinding: the stained slides were examined under light microscopy at low and high magnification and scored according to predefined histopathological criteria. based on qualifications and the number of examiners, two examiners were involved: one with mbbs and phd, and the other with mbbs and m.phil. examiners were blinded to the clinical classification as atrophic or progressive.

Histopathological Assessment

the stained slides were examined under light microscopy at lower and higher magnification. the assessment used the histological criteria. each feature was recorded as follows.

Basement Membrane Fragmentation and Delayering

basement membrane was assessed mainly on pas-stained sections. we recorded fragmentation as grade 0 when no fragmentation was seen and grade 1 when fragmentation was present. delayering was recorded as present when separation of the basement membrane from the overlying epithelium was seen and absent when this separation was not seen. these were treated as binary observations in the present analysis.

Epithelial Separation, Fragmentation and Invagination

the epithelial layers were examined for visible separation, breaks or fragmentation and inward invagination. each finding was recorded as present or absent. epithelial separation meant a visible separation of the epithelial layer from the underlying supporting layer, epithelial fragmentation meant visible discontinuity or breaks in the epithelial layers, and epithelial invagination meant inward dipping of the epithelium into the underlying tissue

Goblet-Cell Pattern

goblet cells in the surface epithelium were assessed according to their arrangement. they were recorded as single goblet cells, clusters of goblet cells, or invagination of goblet cells into the underlying connective tissue.

Stromal Inflammatory Infiltration

inflammatory cells, including neutrophils, monocytes, macrophages, and lymphocytes, were examined under the 40x objective. four microscopic fields were selected. the grading table defined grade 0 as unremarkable stroma or only a few sparse lymphoid cells, and grade 1

as significant patchy or diffuse leukocytic infiltration in at least one 400x microscopic field. the accompanying method text also states that diffusely scattered cells in more than two of the four selected fields were considered grade 1.

Elastosis

elastotic fibers were assessed on verhoeff-stained sections under 10x and 40x objective lenses. we selected four different fields in a zigzag pattern and divided each field into four equal parts, each representing 25% of the field. we assessed elastotic fibers in these fields and calculated an average estimate. we graded elastosis according to the estimated percentage of elastotic material: grade 0 when absent, grade 1 when less than 3%, grade 2 when 3-10%, and grade 3 when more than 10%.

Statistical Analysis

we compared atrophic and progressive groups at the patient level. frequencies and percentages were calculated for categorical findings. fisher exact test was used when comparing binary histological findings because some cell counts were small. for goblet cells, two separate analyses were performed: goblet-cell invagination was treated as a binary finding (present versus absent) and compared using the two-sided fisher exact test, while the overall goblet-cell pattern (single cells, clusters and invagination) was treated as an ordinal variable and compared separately using the mann-whitney u test. for elastosis, high-grade elastosis (>10%) was compared with lower-grade elastosis (≤10%) as a binary variable using fisher exact test, while the full elastosis grade distribution (<3%, 3-10%, >10%) was treated as an ordinal variable and compared using the mann-whitney u test. we considered a two-sided p-value below 0.05 statistically significant.

Results

We included 41 Primary Pterygium Specimens. Thirty-One Lesions (75.6%) were atrophic, and 10 (24.4%) Were Progressive. Most Microscopic Changes Were Common in Both Groups.

Table I. Comparison of Histopathological Findings Between Atrophic and Progressive Pterygium

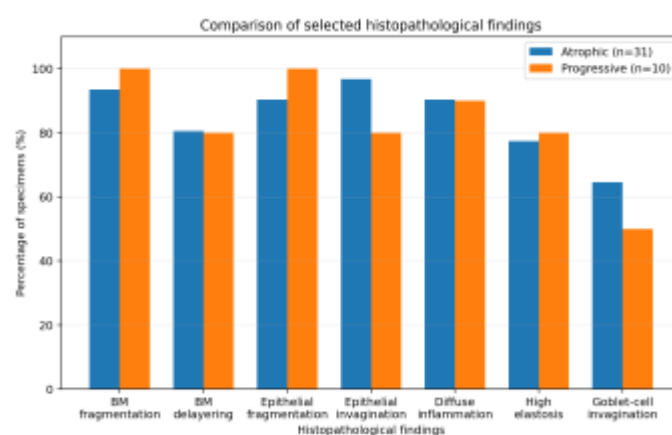
Histopathological Feature	Atrophic (N=31)	Progressive (N=10)	P Value
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Basement Membrane Fragmentation	29 (93.5%)	10 (100.0%)	1.000
Basement Membrane Delayering	25 (80.6%)	8 (80.0%)	1.000
Epithelial Separation	28 (90.3%)	9 (90.0%)	1.000
Epithelial Fragmentation	28 (90.3%)	10 (100.0%)	0.564
Epithelial Invagination	30 (96.8%)	8 (80.0%)	0.142
Diffuse Stromal Inflammation	28 (90.3%)	9 (90.0%)	1.000
Goblet-Cell Invagination (Binary: Present Vs Absent)	20 (64.5%)	5 (50.0%)	0.472†
Overall Goblet-Cell Pattern (Ordinal: Single / Cluster / Invagination)	7 (22.6%) / 4 (12.9%) / 20 (64.5%)	2 (20.0%) / 3 (30.0%) / 5 (50.0%)	0.589‡
High-Grade Elastosis (>10% Vs ≤10%)	24 (77.4%)	8 (80.0%)	1.000*

*for elastosis, $p=1.000$ is from the two-sided fisher exact test comparing high-grade (>10%) with lower-grade (≤10%) elastosis. we analyzed the full ordinal elastosis grade distribution (<3%, 3-10%, >10%) separately using the mann-whitney u test ($p=0.849$). †for goblet cells, $p=0.472$ is from the two-sided fisher exact test for the binary comparison of invagination present versus absent. ‡the $p=0.589$ value is from the separate mann-whitney u comparison of the overall ordinal goblet-cell pattern (single cells, clusters and invagination). basement membrane fragmentation was almost universal in both groups. it was seen in 29 of 31 atrophic lesions and all 10 progressive lesions. basement membrane delayering was present in 25 of 31 (80.6%) atrophic specimens and 8 of 10 (80.0%) progressive specimens. these proportions were close, but the small progressive group means equivalence cannot be concluded from the non-significant comparison. epithelial invagination showed the largest numerical difference. it was present in 96.8% of atrophic lesions compared with 80.0% of progressive lesions, but this difference was not

statistically significant ($p=0.142$). because only 10 progressive specimens were included, the non-significant pvalue does not exclude a true difference between the groups. diffuse stromal inflammation was present in around 90% of both atrophic and progressive specimens. high-grade elastosis (>10%) was present in 24 of 31 (77.4%) atrophic lesions and 8 of 10 (80.0%) progressive lesions. when elastosis was analyzed as a binary variable, comparing high-grade (>10%) with lower-grade elastosis (≤10%), the fisher exact test gave $p=1.000$. in a separate analysis, the overall ordinal distribution of elastosis grades (<3%, 3-10%, >10%) gave $p=0.849$ with the mann-whitney u test. these two p values refer to two different analyses of elastosis rather than conflicting results. neither non-significant result should be interpreted as evidence that the elastosis pattern is equivalent between the two groups. for goblet cells, we performed two separate analyses. in the binary comparison, goblet-cell invagination was present in 20 of 31 (64.5%) atrophic lesions and 5 of 10 (50.0%) progressive lesions; the two-sided fisher exact test gave $p=0.472$. in the separate ordinal analysis, the overall goblet-cell pattern was distributed as 7 single-cell, 4 cluster, and 20 invagination cases in the atrophic group, and 2 single-cell, 3 cluster, and 5 invagination cases in the progressive group: the mann-whitney u test gave $u=171.0$ and $p=0.589$. therefore, $p=0.472$ and $p=0.589$ refer to two different goblet-cell analyses and are not conflicting values. these non-significant p-values do not establish equivalence of the goblet-cell findings between the two groups.

Figure 1. Comparison of selected histopathological findings in atrophic and progressive primary pterygium



Discussion

The Present Analysis Did Not Detect Statistically Significant Differences in Epithelial, Basement Membrane, or Stromal Features Between Atrophic and Progressive Pterygia. However, this should not be interpreted as evidence that the two clinical groups are histopathologically equivalent because the progressive group contained only 10 specimens, and the study had limited statistical power. This Is An Important Observation Because It Suggests That A Simple Clinical Label May Not Completely Represent The Biological Changes Inside A Pterygium. Recent work has shown that some histopathological findings may relate to redness, vascularity, or lesion severity, but the relationship is not always consistent [5-10]. In Our Specimens, Basement Membrane Fragmentation, Epithelial Fragmentation And Epithelial Invagination Were Very Frequent In Both Atrophic And Progressive Lesions. These changes show that disruption of the epithelial-basement membrane region is not limited to clinically progressive disease. Even A Lesion That Was Recorded Clinically As Atrophic Before Surgery May Already Have Marked Microscopic Architectural Disturbance. Epithelial Invagination Was Present In 96.8% Of Atrophic Lesions And 80.0% Of Progressive Lesions. Although This Was The Largest Numerical Difference In Our Comparison, It Did Not Reach Statistical Significance. However, The Groups Were Unequal (31 Atrophic And 10 Progressive Specimens), And The Progressive Group Was Small. This Reduced The Statistical Power And Precision Of The Comparison And Increased The Chance Of Missing A True Difference (Type II error). Therefore, A True Difference Cannot Be Ruled Out, and the non-significant result should not be interpreted as proof that the two groups are the same. A larger study with more balanced groups would be needed to assess this relationship more reliably. Stromal Inflammation Was Also Common In Both Groups. This fits with recent work showing that inflammation remains an important part of pterygium biology. Studies Published In 2024 and 2025 have continued to show the role of inflammatory and vascular activity in disease severity and tissue remodeling [8,9,16-18]. Elastosis Was Another Frequent Finding In The Present Analysis. More than 10% Elastosis Was Present In About Three-Quarters Of Atrophic Lesions And Four-Fifths Of Progressive Lesions. The Statistical Comparisons Were Non-Significant, but these findings do not prove that elastosis is equivalent between the two groups. The High Frequency Of Elastosis In Both Groups May Be Related To Chronic Environmental And Ultraviolet Injury [1,3,4,19]. The Goblet-Cell Analyses Also Did Not Show Statistically Significant Between-

Group Differences. However, Because the Groups Were Small and Unequal, These Findings Should Not Be Used To Conclude That The Goblet-Cell Patterns Were Equivalent. Modern clinical studies have shown that pterygium morphology has several dimensions, Including Size, Vascularity, Thickness, and Ocular-Surface Effects [7,8,14,20]. A Broad Atrophic/Progressive Classification May Therefore Be Too Simple To Reflect All Of The Underlying Tissue Changes. The Small Progressive Group Reduced The Ability To Detect Modest Between-Group Differences, So The Absence Of Statistical Significance Does Not Establish Equivalence. Most specimens showed several histological abnormalities, leaving only a few negative cases for comparison. The clinical classification was also broad and not based on a modern photographic or OCT-based grading system. In Addition, the histological variables were mainly recorded as categories rather than continuous measurements. Future Studies Should Use Standardized Slit-Lamp Grading And Digital Histomorphometry, including epithelial thickness, stromal thickness, microvessel density, inflammatory-cell density, and percentage fibrosis or elastosis. The Main Limitations Were The Small Sample Size And Unequal Group Sizes. No formal a priori sample-size calculation was documented for this secondary comparison, And The Analysis Was Based On The 41 Pterygium Specimens Available From The Parent Research Project. The Distribution Of 31 Atrophic And 10 Progressive Lesions Was Not A Planned Equal Allocation. With only 10 Progressive Specimens, The Study Had Limited Statistical Power To Detect Small Or Moderate Differences, And The Chance Of Missing A True Difference (Type II error) Was Increased. Therefore, Interpret the Non-Significant Findings Cautiously and Do Not Consider Them Evidence That the Two Groups Are Equivalent. The high frequency of several histological findings in both groups also left few negative cases for comparison. The Clinical Phenotype Was Based On Routine Clinical Classification Rather Than A Standardized Photographic Grading System.

Conclusion

No Statistically Significant Differences Were Detected In The Measured Epithelial, Basement Membrane, and Stromal Features Between Atrophic and Progressive Primary Pterygia. Because Only 10 Progressive Specimens Were Included, These Non-Significant Findings Do Not Establish Histopathological Equivalence Between The Two Clinical Groups, And A True Difference May Have Been Missed. Larger Studies With More Balanced Groups, detailed clinical grading, and quantitative

histomorphometry are needed to assess these relationships more reliably.

Ethical Approval

The Ethical Review Committee of The Rawalpindi Medical University, Rawalpindi, Pakistan (RMU/Reg-19/Erc/2484/04/2023).

Conflict of Interest

The Authors Declare No Conflict Of Interest.

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Authors' Contributions

Sadia Aman, Ayesha Nasrullah: Conceptualization, study design, data collection, histopathological assessment, interpretation of findings, manuscript drafting, critical revision of the manuscript, final approval of the version to be published, and accountability for all aspects of the work.

Sumera Khalil, Abdullah Rafique: Study design, histopathological assessment, data curation, literature review, interpretation of findings, manuscript revision, final approval of the version to be published, and accountability for all aspects of the work.

Sanah Sameen, Maha Noor: Data collection, histopathological assessment, data curation, literature review, manuscript drafting and revision, final approval of the version to be published, and accountability for all aspects of the work.

All authors: Reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work in accordance with ICMJE authorship criteria.

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