Article

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Histopathological Severity Is the Strongest Independent Prognostic Factor of Sperm Retrieval in Men With Non-Obstructive Azoospermia Undergoing Microdissection Testicular Sperm Extraction

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Background: The most widely used method for obtaining sperm from men with non-obstructive azoospermia (NOA) is microdissection testicular sperm extraction (micro-TESE), although the mechanisms underlying sperm retrieval remain debated. This study aimed to investigate factors affecting sperm retrieval success in men with NOA undergoing micro-TESE, including clinical, hormonal, genetic, inflammatory, and histological parameters.

Methods: This retrospective study included 135 male patients with NOA who underwent micro-TESE between 2014 and 2025. Testicular histology, systemic inflammatory markers, blood hormone levels, and genetic information were investigated. Histopathological severity was evaluated with the Johnsen scoring system. Univariable and multivariable logistic regression analyses were used to determine independent predictors of successful sperm retrieval.

Results: A total of 71 patients (52.6%) achieved successful sperm retrieval. The Johnsen score was the strongest predictor of sperm retrieval success in both univariable analysis (odds ratio [OR] = 1.65, 95% confidence intervals [CI] = 1.40–1.95; $p < 0.001$) and multivariable analysis, in which patients with mild histopathology had markedly higher odds of retrieval than those with severe histopathology (OR = 26.95, 95% CI = 6.85–106.03; $p < 0.001$). Although serum LH levels were significantly lower in the sperm retrieval–positive group on univariable testing ($p = 0.017$), this association did not reach significance in logistic regression analysis (OR = 0.95, 95% CI = 0.89–1.01; $p = 0.093$). No independent correlations were identified between sperm retrieval outcomes and other hormonal levels, systemic inflammatory markers, genetic abnormalities, or the presence of varicocele.

Conclusion: The Johnsen score was the strongest independent predictor of successful sperm retrieval in patients with non-obstructive azoospermia undergoing micro-TESE. These findings underline the crucial role of histology in postoperative counseling and in planning repeat surgical interventions in men with NOA.

Keywords: azoospermia; non-obstructive azoospermia; microdissection testicular sperm extraction; sperm retrieval; testicular histopathology; Johnsen score; spermatogenesis; male infertility

Introduction

Non-obstructive azoospermia (NOA) is a complex form of male infertility that is difficult to treat because multiple, often interacting factors cause failure of sperm production. Although surgical sperm retrieval has facilitated biological parenthood for some individuals, outcomes remain uncertain, highlighting the need for enhanced patient selection methodologies [1,2]. Microdissection testicular sperm extraction (micro-TESE) is currently regarded as the superior technique, as it yields a greater quantity of sperm while preserving more testicular tissue compared to traditional methods [2,3].

Micro-TESE is a widely employed technique; however, sperm retrieval success rates with this method vary considerably among patients. This is due to the distinct underlying testicular pathology in each instance [4–6]. Due to this diversity, extensive research has focused on clinical, hormonal, genetic, and inflammatory factors that can predict effectiveness. However, no non-invasive biomarker has proven accurate or consistent enough to predict sperm retrieval outcomes in men with NOA [7,8].

Serum hormone level measurements, such as testosterone and follicle-stimulating hormone, are commonly used as indirect indicators of spermatogenic activity; however, their predictive validity varies across different studies [9,10]. Similarly, despite growing interest in systemic inflammatory indices as potential predictive markers, the results have been disappointing and show limited reproducibility across cohorts [11]. Y-chromosome microdeletions and chromosomal abnormalities are important genetic factors in identifying the underlying etiology and guiding

clinical management. However, a patient's genetic profile does not reliably predict surgical sperm retrieval outcomes [12–14].

By contrast, testicular histopathology has consistently shown strong associations with sperm retrieval outcomes and has provided direct insights into sperm production in the testis. For instance, Johnsen scoring and tissue patterns are closely related to localized sperm production, which underpins the rationale for microsurgical exploration during micro-TESE [15,16]. Furthermore, heterogeneity within the testicular tissue diminishes the value of systemic blood tests or single-sided biopsies [17].

Comprehensive evaluation of clinical, hormonal, genetic, inflammatory, and histological aspects is essential, as uncertainty remains regarding definitive markers of sperm retrieval in NOA. This study aimed to evaluate sperm retrieval outcomes after micro-TESE in patients with NOA and to identify independent predictors of success, with a focus on the importance of histopathological findings relative to non-invasive indicators.

Methods

Study Design and Patient Population

This study initially identified 136 male patients with NOA who had micro-TESE at Trakya University Hospital between January 2014 and December 2025. The extended inclusion period was necessary to achieve an adequate sample size, given the relatively low annual incidence of micro-TESE procedures at a single center. Throughout this period, the surgical technique, histopathological evaluation protocol, and laboratory standards remained consistent at our institution. All medical records were collected and systematically reviewed to identify patients with available clinical, laboratory, genetic, and tissue data.

Patients with incomplete records of sperm retrieval outcomes were excluded from the study. One patient was excluded due to missing sperm retrieval outcome data, resulting in a final cohort of 135 patients. Inclusion criteria were: (1) a confirmed diagnosis of NOA based on at least two azoospermic semen analyses and elevated serum FSH; (2) undergoing micro-TESE at Trakya University Hospital; and (3) the availability of sperm retrieval outcome data. Exclusion criteria were: (1) obstructive azoospermia; (2) a history of testicular malignancy or prior chemotherapy/radiotherapy; and (3) missing sperm retrieval outcome data. Consequently, all participants included in the final analysis had clearly defined TESE outcomes, categorized as positive or negative. The primary objective was to obtain sperm, defined specifically as the identification of at least one viable spermatozoon through micro-TESE.

The study was conducted in compliance with the Declaration of Helsinki. The Institutional Review Board of Trakya University approved the study protocol (approval number: 2026/32). The Institutional Review Board waived the requirement for informed consent because the study involved retrospective analysis of previously collected data.

Clinical and Hormonal Evaluation

Demographic data, including age, were retrieved from patients' medical records. During preoperative assessment, levels of follicle-stimulating hormone (FSH), luteinizing hormone (LH), total testosterone, and prolactin were measured in fasting morning blood samples.

Each patient's FSH/LH ratio was calculated and recorded. Clinical varicocele was diagnosed based on physical examination findings and confirmed by scrotal ultrasonography. Genetic test results, including karyotype analysis and Y-chromosome microdeletion testing, were recorded. For statistical analysis, genetic abnormalities were categorized as present (including Klinefelter syndrome [47,XXY; n = 8] and Y-chromosome microdeletions [n = 15]) or absent (n = 107) because the limited number of patients in each subgroup precluded meaningful subgroup analyses. Testicular volume, serum inhibin B, and other clinical parameters were not routinely recorded for all patients during the study period and were therefore not included in the analysis.

Hormonal assays (FSH, LH, total testosterone, and prolactin) were performed using the Cobas e 801 immunoassay analyzer (Roche Diagnostics, Mannheim, Germany). Complete blood count measurements were obtained using the BC-6200 automated hematology analyzer (Mindray, Shenzhen, China). Scrotal color Doppler ultrasonography was performed using the MyLab 40 ultrasound system with an EC1123 endocavitary transducer (Esaote S.p.A., Genoa, Italy).

Systemic Inflammatory Markers

Preoperative complete blood count measurements obtained within one month prior to the procedure were used to derive systemic inflammatory markers. The neutrophil-to-lymphocyte ratio (NLR) was calculated by dividing the neutrophil count by the lymphocyte count. The platelet-to-lymphocyte ratio (PLR) was determined by dividing the platelet count by the lymphocyte count. The systemic immune-inflammation index (SII) was calculated as (platelet count × neutrophil count) / lymphocyte count.

Histopathological Evaluation

An experienced pathologist, blinded to the sperm retrieval results, examined testicular biopsy specimens obtained during micro-TESE. The Johnsen scoring system was used to conduct a histological evaluation [18]. This method rates spermatogenesis on a scale of 1 to 10. Johnsen scores were classified into three categories for categorical analyses: mild (scores 7–9), moderate (scores 4–6), and severe (scores 1–3). The impact of histopathological severity on sperm retrieval outcomes was examined using the aforementioned categories.

Micro-TESE Procedure

All patients underwent micro-TESE under the Universa 300 operating microscope (Möller-Wedel GmbH, Wedel, Germany) and received either general or regional anesthesia. A longitudinal scrotal incision was made for each testis, followed by a single longitudinal incision through the tunica albuginea to widely expose the testicular parenchyma. Seminiferous tubules from the upper pole, mid-portion, and lower pole of the testis were systematically examined. Tubules with a larger, more opaque appearance were sampled, as these were more likely to exhibit active spermatogenesis. Procedures were performed by five experienced urologists specializing in microsurgery for male infertility. An experienced embryologist immediately examined the samples to evaluate the presence of spermatozoa. Detection of at least one live spermatozoon during the procedure indicated successful sperm retrieval. Intraoperative sperm identification and quality assessment were performed using the IX71 inverted microscope (Olympus Corporation, Tokyo, Japan).

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA) Normality of continuous variables was assessed using the Shapiro–Wilk test. As the variables were not normally distributed, data are presented as medians and interquartile ranges (IQRs). Categorical variables are reported as counts and percentages.

The Mann–Whitney U test was used to compare continuous variables, and the chi-square test was used to compare categorical data between the TESE-negative and TESE-positive groups. Univariable logistic regression analyses were conducted to identify factors associated with successful sperm retrieval. The multivariable logistic regression model incorporated variables that either had $p < 0.10$ in univariable analysis or were considered clinically relevant in the established literature, including age, FSH, NLR, varicocele, and genetic mutation status. Although LH showed a borderline association in univariable analysis ($p = 0.093$), it was excluded from the multivariable model due to its strong collinearity with FSH (Spearman r = +0.787, $p < 0.001$), which precluded their simultaneous inclusion. The Johnsen score was included as the primary variable of interest. Prior to model construction, collinearity among all model variables was assessed using Spearman correlation analysis; all variable pairs demonstrated weak-to-moderate correlations ($|r| \leq 0.35$), well below the threshold for clinically significant collinearity ($|r| > 0.70$). Analyses were performed using available data for each variable; the multivariable model included 104 patients with complete covariate data. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported. The discriminative ability of the Johnsen score for predicting sperm retrieval success was assessed using receiver operating characteristic (ROC) curve analysis. The area under the curve (AUC) with 95% confidence intervals was calculated, and the optimal cut-off value was determined using the Youden index, with the corresponding sensitivity and specificity reported. A two-sided p-value of less than 0.05 was considered statistically significant.

Results

Of the 136 male patients who underwent micro-TESE, one patient was excluded because sperm retrieval outcome data were missing. The final study cohort consisted of 135 patients (Fig. 1). While 64 patients (47.4%) had a negative TESE result, 71 (52.6%) had successful sperm retrieval.

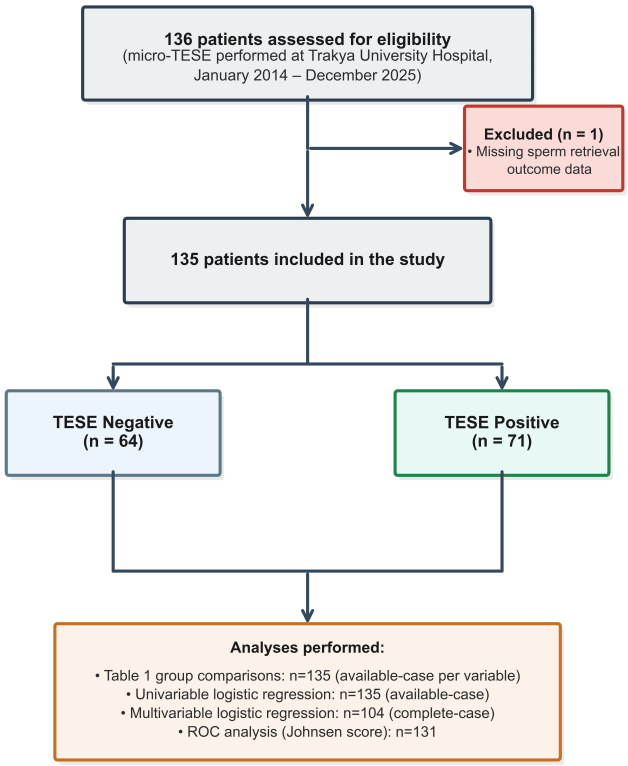

Fig. 1. Flowchart of patient selection and analysis populations. Among 136 male patients with non-obstructive azoospermia who underwent microdissection testicular sperm extraction at Trakya University Hospital between January 2014 and December 2025, one patient was excluded because of missing sperm retrieval outcome data. The final analysis included 135 patients (64 TESE-negative, 71 TESE-positive). TESE, testicular sperm extraction; ROC, receiver operating characteristic.

Table 1 presents the baseline demographic, hormonal, inflammatory, genetic, and histopathological characteristics associated with sperm retrieval outcomes. The median age was nearly identical for the TESE-negative and TESE-positive groups (32.0 [30.0–37.0] years vs. 33.0 [31.0–38.5] years, $p = 0.237$).

Table 1. Baseline demographic, clinical, laboratory, and histopathological characteristics according to sperm retrieval outcome.

Variable	TESE negative (n = 64)	TESE positive (n = 71)	Statistic	*p* value
Age (years)	32.0 (30.0–37.0)	33.0 (31.0–38.5)	z = −1.050	0.237
FSH	19.4 (10.2–26.0)	14.5 (5.85–26.0)	z = 1.348	0.142
LH	8.15 (5.04–12.30)	6.00 (3.42–11.50)	z = 2.257	**0.017**
Total testosterone	3.20 (2.08–4.41)	3.00 (2.00–4.08)	z = 0.299	0.767
Prolactin	8.00 (6.00–11.00)	8.50 (6.30–12.00)	z = −0.469	0.676
FSH/LH ratio	2.15 (1.64–2.62)	2.03 (1.62–3.30)	z = −0.526	0.603
NLR	1.71 (1.36–2.13)	1.69 (1.33–2.25)	z = −0.241	0.684
PLR	102.7 (83.3–126.4)	104.4 (83.2–120.5)	z = 0.192	0.907
SII	415.9 (324.2–501.9)	432.8 (329.2–537.3)	z = −0.514	0.511
Johnsen score	2.0 (2.0–4.0)	8.0 (5.0–8.0)	z = −6.080	<**0.001**
Johnsen category, n (%)[1]			χ^2 = 39.52	<**0.001**
- Severe (1–3)	38 (63.3%)	13 (18.3%)		
- Moderate (4–6)	15 (25.0%)	13 (18.3%)		
- Mild (7–9)	7 (11.7%)	45 (63.4%)		
Genetic mutation, n (%)[2]	14 (22.6)	9 (13.8)	χ^2 = 1.097	0.295
Varicocele, n (%)[3]	20 (33.3)	12 (20.3)	χ^2 = 1.946	0.164

Values are presented as median (interquartile range) or as number (%). Statistically significant *p*-values (<0.05) are shown in bold. Continuous variables were compared using the Mann–Whitney U test, and categorical variables were compared using the chi-square test. TESE, testicular sperm extraction; FSH, follicle-stimulating hormone; LH, luteinizing hormone; NLR, neutrophil-to-lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; SII, systemic immune-inflammation index.

[1] Johnsen category data were available for 131 of 135 patients (4 TESE-negative patients had no histopathological result). Percentages are calculated based on available data (n = 60 negative, n = 71 positive).

[2] Genetic mutation data were available for 127 of 135 patients (n = 62 TESE-negative, n = 65 TESE-positive). Percentages are calculated based on available data only.

[3] Varicocele data were available for 119 of 135 patients (n = 60 TESE-negative, n = 59 TESE-positive). Percentages are calculated based on available data only.

Those with successful sperm retrieval had significantly lower serum LH levels than those with negative TESE results (6.00 [3.42–11.50] vs. 8.15 [5.04–12.30], $p = 0.017$). FSH, total testosterone, prolactin levels, and the FSH/LH ratio did not differ significantly between groups (all $p > 0.05$).

Systemic inflammatory indices, such as the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and systemic immune-inflammation index (SII), did not differ significantly between TESE-negative and TESE-positive patients (all $p > 0.05$).

The prevalence of genetic abnormalities did not differ significantly between patients with negative and positive sperm retrieval results (22.6% vs. 13.8%, $p = 0.295$). The presence of clinical varicocele was not associated with sperm retrieval success (33.3% vs. 20.3%, $p = 0.164$).

Histopathological results showed a strong association with sperm retrieval. The median Johnsen score was significantly elevated in the TESE-positive group relative to the TESE-negative group (8.0 [5.0–8.0] vs 2.0 [2.0–4.0], $p < 0.001$). A significant difference ($p < 0.001$) was observed between the two groups in the distribution of Johnsen severity categories. Patients with successful sperm retrieval exhibited a significantly higher percentage of cases with mild histopathology (Table 1). Table 2 presents univariable and multivariable logistic regression analyses of factors that may enhance sperm production. The Johnsen score demonstrated the strongest association with sperm retrieval success. Each one-point increment in the score corresponded to a 65% increase in the likelihood of sperm retrieval (OR = 1.65, 95% CI = 1.40–1.95; $p < 0.001$).

Although serum LH levels were significantly lower in the TESE-positive group as assessed by the Mann–Whitney U test ($p = 0.017$), this association did not reach statistical significance in univariable logistic regression analysis (OR = 0.95, 95% CI = 0.89–1.01; $p = 0.093$), which is attributable to methodological differences between rank-based and logistic regression approaches. Furthermore, univariable analyses showed no significant associations between sperm retrieval outcomes and the remaining variables, including age, FSH, testosterone, prolactin, genetic mutation status, varicocele, and inflammatory indices such as NLR, PLR, and SII (all $p > 0.10$).

Receiver operating characteristic curve analysis confirmed the strong discriminatory ability of the Johnsen score for predicting sperm retrieval success, with an area under the curve (AUC) of 0.816 (95% CI: 0.739–0.881; $p <$

Table 2. Univariable and multivariable logistic regression analyses for predictors of successful sperm retrieval.

Variable	Univariable OR	Univariable 95% CI	Univariable *p* value	Multivariable OR	Multivariable 95% CI	Multivariable *p* value
Age	1.03	0.97–1.09	0.318	0.97	0.88–1.07	0.523
FSH	0.98	0.95–1.01	0.176	1.01	0.98–1.04	0.487
LH	0.95	0.89–1.01	0.093	-	-	-
Testosterone	0.97	0.74–1.27	0.824	-	-	-
Prolactin	1.01	0.95–1.07	0.723	-	-	-
NLR	1.28	0.70–2.35	0.420	1.18	0.47–2.99	0.722
PLR	1.00	0.99–1.01	0.577	-	-	-
SII	1.00	0.99–1.003	0.390	-	-	-
Varicocele (yes)	0.51	0.22–1.17	0.113	0.48	0.16–1.48	0.202
Genetic mutation (yes)	0.55	0.23–1.33	0.186	1.03	0.29–3.64	0.969
Johnsen score (continuous)	1.65	1.40–1.95	**<0.001**	-	-	-
Mild vs Severe (Johnsen 7–9 vs ≤3)	-	-	-	26.95	6.85–106.03	**<0.001**
Moderate vs Severe (Johnsen 4–6 vs ≤3)	-	-	-	2.32	0.72–7.45	0.158

Odds ratios (ORs) are presented with 95% confidence intervals (CIs). The multivariable analysis included 104 of 135 patients with complete covariate data and was adjusted for age, follicle-stimulating hormone, varicocele, genetic mutation status, and neutrophil-to-lymphocyte ratio. A two-sided p value < 0.05 was considered statistically significant. Statistically significant p-values (<0.05) are shown in bold.

0.001). The optimal cut-off value was a Johnsen score of 6, yielding a sensitivity of 71.8% and a specificity of 85.0% (Fig. 2)

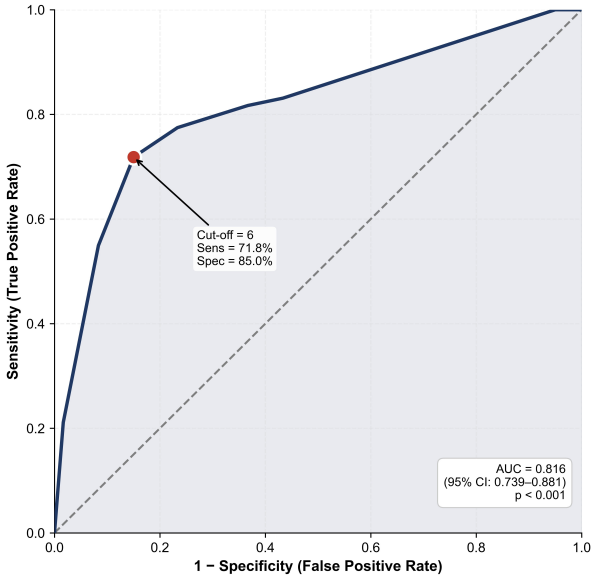

Fig. 2. Receiver operating characteristic (ROC) curve of the Johnsen score for predicting sperm retrieval success in patients undergoing micro-TESE. AUC, area under the curve; CI, confidence interval; ROC, receiver operating characteristic; Sens, sensitivity; Spec, specificity.

The Johnsen score was analyzed as a continuous variable in univariable analysis (OR per 1-unit increment) and as a categorical variable (mild [7–9] vs. severe [≤3]; moderate [4–6] vs. severe) in multivariable analysis, with the severe category as the reference group.

Table 2 summarizes the results of a multivariable logistic regression analysis examining NLR, age, FSH, varicocele, and genetic mutation status. After adjustment for covariates, histopathological severity remained the strongest independent predictor of successful sperm retrieval. Patients with a mild Johnsen category had a markedly increased probability of TESE positivity compared with those with severe histology (OR = 26.95, 95% CI: 6.85–106.03; $p < 0.001$). The moderate Johnsen category did not show a statistically significant association with sperm retrieval success (OR 2.32, 95% CI 0.72–7.45; $p = 0.158$).

Discussion

The present study demonstrated that male patients with NOA achieved a sperm retrieval rate of 52.6% using microdissection testicular sperm extraction. This result is consistent with recent studies that endorse micro-TESE as the optimal surgical method for this challenging cohort [1,2,4]. Micro-TESE is superior to conventional TESE, particularly in cases of substantial testicular failure, as it precisely identifies localized spermatogenesis while minimizing tissue loss [2,3].

Among the various evaluated characteristics, histopathological severity, measured by the Johnsen score, was identified as the strongest independent predictor of successful sperm retrieval.

Our findings are consistent with prior research showing that testicular histology is the most reliable indicator of residual spermatogenesis in men with NOA [15,16]. The superiority of tissue-level assessment over systemic or indirect biomarkers is scientifically supported by the mosaic distribution of spermatogenesis.

Although histopathological evaluation in this study was performed intraoperatively rather than preoperatively, its role should not be viewed solely as a limitation. As previously demonstrated in the literature, histopathological findings obtained during micro-TESE can serve as a reliable prognostic indicator for patients being considered for repeat surgical sperm retrieval, guiding individualized counseling regarding the likelihood of success in subsequent attempts [19]. Furthermore, while preoperative diagnostic biopsy has been proposed as a strategy to obtain histological information before micro-TESE, this approach is generally considered impractical due to the added surgical burden and associated risks [20]. Moreover, in centers where preoperative diagnostic biopsy is routinely performed prior to micro-TESE, the Johnsen score obtained at that stage would serve as a true preoperative prognostic factor, further underscoring the broader clinical relevance of the present findings [19,21].

FSH, testosterone, prolactin, and the FSH/LH ratio did not independently correlate with successful sperm retrieval in our sample. Certain hormonal profiles have been linked to micro-TESE outcomes in several studies, but these associations are inconsistent and lack sufficient predictive accuracy when assessed separately [8,9,22]. As recent reviews and studies of predictive models increasingly indicate, blood hormone levels alone are insufficient for accurate clinical decision-making [7,10].

Similarly, in our study, sperm retrieval was not predicted by systemic inflammatory markers such as the neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio, and systemic immune-inflammation index. In certain cohorts, inflammatory markers have been proposed as non-invasive predictors; however, their efficacy is limited and may be impacted by non-gonadal physiological factors. Our findings suggest that spermatogenic activity in the testis is not always reflected by systemic inflammation.

Sperm retrieval success was not independently influenced by genetic abnormalities, including chromosomal aberrations and Y chromosome microdeletions. While men with AZFa or AZFb deletions have had unfavorable outcomes, some men with AZFc microdeletions have had favorable outcomes. When histopathology is favorable, genetic findings alone may not preclude successful sperm retrieval [12,14]. These findings underscore the importance of individualized patient counseling based on histopathological evaluation, rather than relying solely on genetic status to preclude surgical sperm retrieval.

Our study also found that clinical varicocele did not improve sperm retrieval outcomes. Some studies indicate that varicocelectomy may assist certain NOA patients in obtaining sperm or enhance assisted reproductive outcomes; however, the evidence is inconsistent and significantly influenced by underlying histological patterns [23,24]. Routine varicocelectomy solely to enhance micro-TESE outcomes cannot be universally accepted.

Studies documenting marked heterogeneity of spermatogenesis within the testis support the strong predictive power of the Johnsen score observed in this study. These results highlight the necessity of microsurgical evaluation and confirm histopathology as the most reliable prognostic indicator currently available.

This study has several limitations. First, the retrospective design and single-center setting may limit generalizability. Second, the small sample size (n = 135) may have reduced statistical power. Third, the inclusion period (2014–2025) spans a time frame during which laboratory standards and surgical experience may have evolved, thereby introducing potential heterogeneity. Fourth, genetic abnormalities were categorized as present or absent, without further subclassification by mutation subtype. Although Klinefelter syndrome (n = 8) and Y-chromosome microdeletions (n = 15) were identified separately in our dataset, the limited sample size in each subgroup precluded statistically meaningful analyses. Future studies with larger cohorts should evaluate the differential prognostic implications of specific genetic subtypes on micro-TESE outcomes. Fifth, as procedures were performed by five different surgeons, inter-surgeon variability in technique and experience may represent an additional source of heterogeneity. Sixth, certain clinical parameters, such as testicular volume and serum inhibin B, were not available for all patients, as these are not routinely assessed at our institution, which may represent an additional limitation of this study.

Conclusion

In conclusion, this study demonstrates that the strongest independent predictor of successful sperm retrieval in male patients with NOA undergoing micro-TESE is the histopathological severity as determined by the Johnsen score. Hormonal, inflammatory, genetic, and clinical factors did not independently predict outcomes after adjustment for histology, highlighting the crucial role that testicular histopathology plays in postoperative patient counseling and planning individualized repeat surgical interventions. Incorporating histopathological assessment into clinical algorithms may improve patient selection, set realistic expectations, and avoid unnecessary surgical interventions.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

CÖ, HCK, BB, AÇ, and GÇ contributed to the conception and design of the study, data acquisition, and analysis and interpretation of the data. CÖ, HCK, and BB drafted

the manuscript. AÇ and GÇ revised it critically for important intellectual content. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Trakya University Institutional Review Board (approval number: 2026/32). The study was conducted in accordance with the Declaration of Helsinki. The Institutional Review Board waived the requirement for informed consent due to the retrospective design of the study.

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Conflict of Interest

The authors declare no conflict of interest.

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