

ORIGINAL RESEARCH ORJİNAL ARAŞTIRMA

DOI: 10.5336/ophthal.2025-109749

The Impact of Androgenetic Alopecia on Ocular Health: An Investigation of Dry Eye and Meibomian Gland Dysfunction: Cross-Sectional Study

Androjenetik Alopesi'nin Göz Sağlığı Üzerindeki Etkisi: Kuru Göz ve Meibomian Bez Disfonksiyonunun İncelenmesi: Kesitsel Çalışma

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ABSTRACT Objective: To investigate the impact of androgenetic alopecia on ocular health, particularly focusing on dry eye disease and meibomian gland dysfunction in female patients. **Material and Methods:** A cross-sectional observational study was conducted involving 28 eyes of female patients diagnosed with androgenetic alopecia and 32 eyes of healthy controls. Participants underwent dry eye tests, including the Schirmer-I test, Oxford score, and Ocular Surface Disease Index. Meibomian gland morphology was evaluated using dynamic meibography, and tear film stability was assessed through non-invasive tear breakup time and tear meniscus height measurements. Meibomian gland quality and function were graded using standardized scoring systems. **Results:** Although patients with androgenetic alopecia exhibited higher Schirmer-I test values and Oxford scores compared to controls, the differences were not statistically significant. Similarly, no significant differences were found in Ocular Surface Disease Index, non-invasive tear breakup time, tear meniscus height, or blink rate. Meiboscores were comparable between both groups. However, meibum quality was significantly better in the androgenetic alopecia group ($p=0.001$). **Conclusion:** While androgenetic alopecia may influence meibomian gland function, this study found no significant differences in dry eye parameters between androgenetic alopecia patients and healthy controls. These findings suggest that the hormonal interplay between sex steroids and the ocular surface is complex, and further research with larger cohorts is needed to fully understand the ocular implications of androgenetic alopecia.

ÖZET Amaç: Bu çalışmanın amacı, kadın hastalarda androjenetik alopesinin oküler sağlık üzerindeki etkisini incelemek, özellikle kuru göz hastalığı ve meibomian bezi disfonksiyonu ile olan ilişkisini değerlendirmektir. **Gereç ve Yöntemler:** Androjenetik alopesi tanısı konmuş kadın hastalara ait 28 göz ve sağlıklı kontrol grubuna ait 32 gözün dâhil edildiği kesitsel gözlemsel bir çalışma yürütülmüştür. Katılımcılara Schirmer-I testi, Oxford skoru ve Oküler Yüzey Hastalık İndeksi gibi kuru göz testleri uygulanmıştır. Meibomian bezi morfolojisi, dinamik meibografi ile değerlendirilmiş, gözyaşı filmi stabilitesi, invaziv olmayan gözyaşı kırılma süresi ve gözyaşı menisküs yüksekliği ölçümleri ile analiz edilmiştir. Meibomian bezi kalitesi ve fonksiyonu, standart skorlamalar kullanılarak derecelendirilmiştir. **Bulgular:** Androjenetik alopesili hastalarda Schirmer-I testi değerleri ve Oxford skorları, kontrol grubuna kıyasla daha yüksek olmasına rağmen bu fark istatistiksel olarak anlamlı bulunmamıştır. Aynı şekilde Oküler Yüzey Hastalık İndeksi, invaziv olmayan gözyaşı kırılma süresi, gözyaşı menisküs yüksekliği ve göz kırpma hızı açısından da anlamlı bir farklılık saptanmamıştır. Meiboskor değerleri, her iki grupta benzer bulunmuştur. Ancak meibum kalitesi, androjenetik alopesi grubunda anlamlı derecede daha iyi olarak tespit edilmiştir ($p=0.001$). **Sonuç:** Androjenetik alopesi, meibomian bezi fonksiyonunu etkileyebilecek bir faktör olmakla birlikte bu çalışmada, androjenetik alopesi hastaları ile sağlıklı kontroller arasında kuru göz parametreleri açısından anlamlı bir fark bulunmamıştır. Bu bulgular, cinsiyet steroidleri ile oküler yüzey arasındaki hormonal etkileşimin karmaşık bir yapıya sahip olduğunu göstermekte olup, androjenetik alopesinin oküler etkilerini tam olarak anlayabilmek için daha geniş hasta grupları ile yapılacak ileri çalışmalara ihtiyaç duyulduğunu ortaya koymaktadır.

Keywords: Androgenetic alopecia; dry eye disease; meibomian gland dysfunction; sex steroids; female pattern hair loss

Anahtar Kelimeler: Androjenetik alopesi; kuru göz hastalığı; meibomian bezi disfonksiyonu; cinsiyet steroidleri; kadın tipi saç dökülmesi

TO CITE THIS ARTICLE:

Hacıağaoğlu S, Aydın FO, Altun E. The impact of androgenetic alopecia on ocular health: An investigation of dry eye and meibomian gland dysfunction: Cross-sectional study. Türkiye Klinikleri J Ophthalmol. 2025;34(4):168-74.

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Peer review under responsibility of Türkiye Klinikleri Journal of Ophthalmology.

Received: 20 Feb 2025

Received in revised form: 05 Jul 2025

Accepted: 24 Jul 2025

Available online: 03 Sep 2025

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Androgenetic alopecia (AGA) is characterized by progressive thinning and reduction of hair follicles in a specific pattern, affecting both men and women.¹ The condition can onset after puberty and tends to worsen with age, being more prevalent, especially among women during the postmenopausal period.² This condition is characterized by the miniaturization of hair follicles and a reduction in hair density, predominantly affecting the central and frontal scalp regions. It is hypothesized that AGA develops due to an increased number of androgen receptors and abnormal sensitivity of hair follicles to circulating androgens.³ By changing testosterone into 5- α -dihydrotestosterone, the enzyme 5- α -reductase plays a vital role in causing hair follicle thinning, which in turn causes terminal hairs to become vellus hairs.^{2,3}

Although traditionally associated with cosmetic and psychological concerns, emerging evidence suggests that AGA may also have systemic implications, including effects on sebaceous glands, such as meibomian glands, which are crucial for ocular surface homeostasis. The interplay between hormonal fluctuations, particularly androgens and estrogens, and meibomian gland function has been highlighted in several studies, suggesting that hormonal imbalances might contribute to dry eye disease (DED) and meibomian gland dysfunction (MGD).^{4,5} Androgens also activate 25 distinct ontologies (with 5 genes) involved in lipid synthesis, homeostasis, transport, and binding, in addition to the dynamics of cholesterol, fatty acids, phospholipids, and steroids.⁶ In the meibomian glands of both male and female mice, testosterone also significantly reduces keratinization.⁷ The fact that topical androgens enhance the synthesis and secretion of meibomian gland lipids, improve meibum quality, extend the tear film breakdown time, and decrease evaporative DED in humans may be explained by these combined androgen actions that promote lipogenesis and decrease keratinization.

DED is a multifactorial condition, with endocrine abnormalities playing a significant role in its etiology.⁸ Physiological factors such as menopause and menstrual cycle changes, as well as conditions like polycystic ovary syndrome and androgen resistance, along with iatrogenic factors such as contra-

ceptive use and antiandrogen therapy, contribute to its development.⁸ The ocular surface epithelium, including the meibomian glands responsible for the tear film's lipid layer, contains receptors for sex steroid hormones.⁹ Androgens stimulate the secretion of both the quantity and quality of lipids from the meibomian glands, whereas estrogens and progesterones inhibit sebaceous gland function, leading to reduced lipid production.⁹

This study aimed to determine whether female patients with AGA were more likely than healthy people to experience MGD and DED.

MATERIAL AND METHODS

This cross-sectional observational study included 28 eyes of 28 patients diagnosed with AGA (Group 1) and 32 eyes of 32 healthy volunteers (Group 2) at Medipol University Hospital. All female patients with AGA were assessed and diagnosed by the same dermatologist (EA) and had not received any prior treatment. Following a comprehensive ophthalmologic examination, participants underwent evaluations including corneal and conjunctival fluorescein staining (Oxford score), and the Schirmer-I test. Subjective symptoms were assessed using the Ocular Surface Disease Index (OSDI) scoring. Meibomian gland morphology was visualized using dynamic meibography (Lipiscan, TearScience Inc., Morrisville, NC, USA). The meibomian glands in each upper and lower eyelid were assessed by the same investigator (SH) using the grading system described by Arita et al., categorizing them into stages based on partial or total loss rates. A meiboscore ranging from 0 to 3 was assigned: Stage 0 (no loss), Stage 1 (less than 1/3 loss), Stage 2 (1/3 to 2/3 loss), and Stage 3 (more than 2/3 loss) (Figure 1).¹⁰ The meiboscores from both upper and lower lids were combined to determine the total meiboscore for each eye. The quality of meibum produced by the glands [meibum quality score (MQS)] was graded as follows: Stage 0 (transparent), Stage 1 (cloudy), Stage 2 (containing debris), and Stage 3 (toothpaste consistency).¹¹ Additionally, non-invasive tear breakup time (NIBUT), tear meniscus height, and the number of blinks per minute were evaluated and recorded using MYAH equipment from Topcon Healthcare Inc., Tokyo,

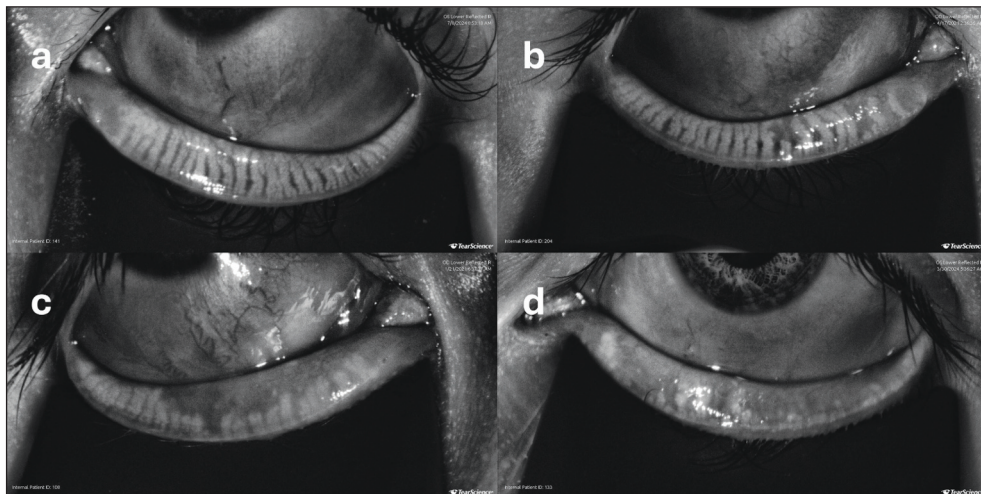


FIGURE 1: a) Stage 0 (no loss); b) Stage 1 (less than 1/3 loss); c) Stage 2 (1/3 to 2/3 loss); d) Stage 3 (more than 2/3 loss)

Japan, for all participants. All tests were conducted in the same examination room and under the same temperature setting.

The study was approved by Medipol University's Institutional Review Board/Ethics Committee (date: September 14, 2022; no: E-10840098-772.02-5297) and strictly followed the Declaration of Helsinki's guidelines. Informed consent was obtained from all participants.

Patients with prior use of tear drops or contact lenses, history of eye surgery with dry eye as a side effect, systemic medications like isotretinoin and diuretics, systemic, ocular, and dermatologic conditions known to cause dry eye, as well as congenital or acquired ocular surface disorders were excluded from the study.

STATISTICAL ANALYSIS

SPSS for Windows (Version 25.0, IBM Corp, NY, USA) was utilized for statistical analysis. Descriptive statistics included mean, standard deviation, and range (minimum-maximum). The Kolmogorov-Smirnov test and box plot graphs assessed the normality of variables. Pairwise comparisons of normally distributed variables employed the student t-test, while variables not following normal distribution were analyzed using the Mann-Whitney U test. Statistical significance was set at $p < 0.05$. Sample size calculation was performed using G*Power (Heinrich-Heine-Universität, Germany) software based on a

preliminary power analysis from Kiyat et al., aiming for a type 1 error rate and power of 0.8, with an estimated sample size of 28 per group.³

RESULTS

The mean ages of Group 1 and Group 2 were 29.5 ± 5.1 and 31.2 ± 9.2 , respectively ($p = 0.527$). Table 1 presents the dry eye test results for both groups. Compared to Group 2, Group 1 had higher Oxford score and Schirmer-I test values, although these differences were not statistically significant ($p = 0.457$ and 0.201 , respectively). There were no significant differences in OSDI score and NIBUT between the groups ($p = 0.857$ and 0.773 , respectively). Although Group 1 had a lower tear meniscus, this disparity was not statistically significant ($p = 0.072$). Additionally, the number of blinks per minute did not differ significantly between the groups ($p = 0.923$).

TABLE 1: Dry eye test measurement results

	Group 1 $\bar{X} \pm SD$ (range)	Group 2 $\bar{X} \pm SD$ (range)	p value
Schirmer-I (mm)	22.71 ± 11.41 (2-35)	19.58 ± 10.32 (5-35)	0.201
Oxford score	0.37 ± 0.42 (0-1)	0.24 ± 0.41 (0-1)	0.457
OSDI score	23.12 ± 13.62 (4.16-45)	22.01 ± 13.32 (2.08-40)	0.857
NIBUT (sn)	14.12 ± 10.73	13.23 ± 9.25	0.773
Tear meniscus (mm)	0.21 ± 0.13 (0.09-0.63)	0.25 ± 0.11 (0.10-0.46)	0.072
Blink (n/min)	17.32 ± 14.43 (2-48)	16.93 ± 11.43 (3-38)	0.923

SD: Standard deviation; OSDI: Ocular Surface Disease Index;
NIBUT: Non-invasive tear break-up time

TABLE 2: MQS scoring and meiboscore results

	Group 1 $\bar{X} \pm SD$ (range)	Group 2 $\bar{X} \pm SD$ (range)	p value
MQS	1.78 $\pm$ 0.43 (1-2)	2.43 $\pm$ 0.48 (2-3)	0.001*
Upper meiboscore	0.38 $\pm$ 0.48 (0-1)	0.28 $\pm$ 0.46 (0-1)	0.532
Lower meiboscore	0.38 $\pm$ 0.71 (0-2)	0.25 $\pm$ 0.53 (0-1)	0.703
Total meiboscore	0.78 $\pm$ 0.67 (0-2)	0.56 $\pm$ 0.72 (0-2)	0.343

*Statistically significant ($p < 0.05$); MQS: Meibum quality score; SD: Standard deviation

Table 2 summarizes the meibography results. Comparison of meiboscores between the groups revealed similar upper, lower, and total meiboscores ($p=0.532$, $p=0.703$, and $p=0.343$, respectively). However, the MGD score of Group 1 was significantly lower compared to Group 2 ($p=0.001$).

DISCUSSION

Female androgenetic alopecia (FAA) is a type of non-scarring hair loss with a complex etiology that predominantly affects postmenopausal women.¹² The onset of FAA typically begins during the reproductive years, with a peak incidence observed during the menopausal period, generally occurring between the ages of 50 and 60.¹² Unlike male pattern baldness, which is well-understood to be influenced by androgens, the role of androgens in FAA remains uncertain. Surprisingly, low levels of androgens do not consistently correlate with FAA, leading to the adoption of the term female pattern hair loss (FPHL) for this condition in women.¹³ This change reflects the unclear relationship between androgens and FPHL, as serum androgen levels may not be elevated in all cases of this condition.¹⁴

Sex steroids exert a complex influence on the tear film and meibomian glands. Current understanding suggests that low circulating androgen levels and high estrogen levels are generally recognized as risk factors for dry eye, either independently or in combination.¹⁵ Meibomian glands have been found to include sex steroid receptors for both estrogen and androgens, which may have an impact on meibum production.¹⁶

Whereas estrogens result in a reduction in lipid production, androgens promote lipid synthesis and

secretion from meibomian glands. Both a reduction in the quality of meibum secretion and alterations in the meibomian gland appearance have been noted in these patients.¹⁷ Elevated blood estradiol levels are thought to raise the risk of dry eye by preventing the formation of lipids and encouraging their breakdown in the meibomian glands, even though the actions of estrogens on the ocular surface of the meibomian glands are less well-established.^{4,16} In a study of women with premature ovarian failure aged 17-43, dry eye symptoms were more common than in an age-matched control group, indicating a positive influence of ovarian estrogen.¹⁸ Three instances of an increased incidence of dry eye in postmenopausal women undergoing aromatase inhibitor therapy for breast cancer underscore the importance of peripheral estrogen production in preserving ocular surface homeostasis.¹⁹ Dry eye is more common among postmenopausal women.²⁰ Lower levels of estrogen and testosterone are among the hormones that change as a result of menopause.²¹ Therefore, these alterations in the levels of circulating sex steroids might be responsible for postmenopausal women's dry eye.²² In addition, the duration of menopause and hormone replacement therapy have been shown to increase the incidence of dry eye.²³⁻²⁵

In a study conducted by Kiyat et al., dry eye tests and meibography results were compared between women with FPHL and age-matched healthy women. The study found that tear film breakup time, a measure of tear film stability, was significantly lower in the FPHL group, whereas the OSDI score, indicating ocular surface disease symptoms, was significantly higher. However, there were no significant differences between the groups in Schirmer-I test and Oxford scores. Subgroup analysis based on menopausal status (postmenopausal vs. non-menopausal) showed similar results in both groups.³ In contrast, our study did not find significant differences in dry eye tests between FPHL patients and healthy subjects. Several factors may contribute to this disparity. Firstly, all participants in our study were in the non-menopausal period, potentially influencing tear production and inflammatory responses differently than in the follicular phase of the menstrual cycle. Subjective discomfort symptoms are notably associated with

hormonal fluctuations during the menstrual cycle.²⁶ Another contributing factor could be the significant impact of androgens on the meibomian gland structure, where they stimulate lipid synthesis and secretion.^{16,27} Furthermore, androgens are known to enhance lacrimal gland function by boosting the production of transforming growth factor beta, which is linked to a decrease in interleukin-1b and tumor necrosis factor alpha levels. This has an anti-inflammatory effect.²⁸

Androgens have been identified as key regulators of lipid synthesis in meibomian glands, enhancing the quality and quantity of lipid secretion, which is essential for tear film stability.⁴ On the other hand, lipid production may be inhibited by estrogens, which could result in evaporative dry eye and unstable tear films. When compared to controls, meibomian glands in patients undergoing anti-androgen therapy show notable alterations, according to several studies. Orifice metaplasia, poorer secretion quality, a noticeable alteration in the meibum's neutral lipid balance, and a morphological appearance typical of severe illness are some of these alterations.^{17,29}

Both men and women see a considerable decline in meibum quality as they age, and meibomian gland orifice metaplasia is far more common.^{30,31} The polar and neutral lipid compositions of meibomian gland secretions also undergo significant alterations with aging.^{30,31} These findings result from the sharp drop in androgen levels in both sexes.³²

In a study comparing male AGA patients with healthy volunteers, statistically significant dry eye findings and MGD were observed in androgenetic alopecia patients.³³ Dry eye and MGD are also significantly observed in patients with sex steroid imbalance such as polycystic ovary syndrome and post-menopausal women.

In the study by Kiyat et al., meiboscores were significantly higher in FPHL patients compared to healthy controls.³ However, our study yielded different findings, with both groups showing similar meiboscores. The FPHL group in our study demonstrated significantly better MQS, potentially linked to differences in serum androgen levels between the groups. This finding may reflect the stimulatory ef-

fects of androgens on meibomian gland function, consistent with Mantelli et al., who highlighted the critical role of androgen imbalance in ocular surface pathophysiology.⁵ Another possible scenario is androgen receptor upregulation. When there is an increased sensitivity to androgens in one area of the body or an imbalance in systemic androgen levels, other tissues may adapt to this situation in different ways. Cells in the meibomian glands may increase the number or sensitivity of androgen receptors as a compensatory mechanism to continue to benefit from the positive effects of androgens.³⁴ Finally, the meibomian glands have the capacity to synthesize and activate their own androgens locally. This allows the gland to function according to the needs of its microenvironment, partially independent of systemic circulating hormone levels. Increased local synthesis of androgens may also be one explanation.³⁵ However, the absence of serum hormone level measurements in our study limits the ability to establish a direct link between androgen levels and the observed differences.

However, our study has several limitations. These include a relatively small sample size, the potential influence of menstrual cycle variations among participants, and the absence of periodic measurements of serum hormone levels, which could fluctuate over time. In addition, not knowing the duration of the disease was one of the limitations.

CONCLUSION

In conclusion, the dry eye parameters observed in FAA patients were similar to those in healthy volunteers, but meibum quality was found to be better. Future research should include larger cohorts and diverse populations, including postmenopausal women, to elucidate the complex interactions between hormonal changes and ocular health. This approach will provide a more comprehensive understanding of the systemic implications of FPHL and its potential role in ocular surface disorders.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that pro-

vides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Sezer Hacıağaoğlu, Ece Altun; **Design:** Sezer Hacıağaoğlu, Fahri Onur Aydın; **Control/Supervision:** Sezer Hacıağaoğlu, Fahri Onur Aydın, Ece Altun; **Data Collection and/or Processing:** Sezer Hacıağaoğlu, Ece Altun; **Analysis and/or Interpretation:** Fahri Onur Aydın, Sezer Hacıağaoğlu; **Literature Review:** Sezer Hacıağaoğlu, Fahri Onur Aydın, Ece Altun; **Writing the Article:** Sezer Hacıağaoğlu, Fahri Onur Aydın, Ece Altun; **Critical Review:** Fahri Onur Aydın.

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