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Features of laser epilation of androgen-dependent areas: Correction of fluence and pulse duration parameters for male skin

Meerim Ramatova*
Beauty Trainer and Consultant
Naked Laser Hair Removal Studio
720005, 108 Gorky Str., Bishkek, Kyrgyz Republic
https://orcid.org/0009-0000-7629-0276

Abstract. The aim of this study was a comparative assessment of the clinical efficacy and safety of a modified laser epilation protocol for androgen-dependent areas in men. A prospective comparative study with a split-body intra-subject design included 52 male patients with Fitzpatrick skin phototypes I-IV. Assessment was carried out using phototrichometry at four control points, subjective tolerability of procedures was recorded using a visual analogue scale, protocol safety was verified through clinical monitoring of adverse reactions, and correlation dependencies were established using Spearman's rank analysis. Upon completion of a full course of 6-8 procedures, the reduction in terminal hair density in the intervention zone was 57.6% versus 40.8% in the control ($t=8.12$; $p<0.001$; Cohen's $d=0.88$). Statistically significant inter-protocol differences persisted at 3 and 6 months after treatment ($p<0.001$), with hair density in the intervention zone being 43.5±9.4 versus 61.3±10.5 hairs/cm² in the control. Subjective tolerability of procedures was identical in both zones – the median pain sensation was 3 points ($Z=1.21$; $p=0.23$). No cases of post-inflammatory hyperpigmentation were recorded in any patient, including 71.1% of participants with skin phototypes III-IV. Fluence and pulse duration acted as independent predictors of efficacy ($\rho=0.62$ and $\rho=0.58$, respectively; $p<0.01$). The obtained results may be used for the development of standardised clinical protocols for laser epilation of androgen-dependent areas in men with moderately and highly pigmented skin, ensuring high therapeutic efficacy

Keywords: terminal hair growth; follicular thermolysis; hair density reduction; selective photothermolysis; post-inflammatory hyperpigmentation

Особливості лазерної епіляції андрогензалежних зон: корекція параметрів флюенсу та тривалості імпульсу для чоловічої шкіри

Меерім Раматова*
Тренер-технолог у сфері краси
Студія лазерної епіляції «Naked»
720005, вул. Горького, 108, м. Бішкек, Киргизька Республіка
https://orcid.org/0009-0000-7629-0276

Анотація. Метою даного дослідження була порівняльна оцінка клінічної ефективності та безпеки модифікованого протоколу лазерної епіляції андроген-залежних зон у чоловіків. У проспективному порівняльному дослідженні з внутрішньосуб'єктним дизайном «split-body» взяли участь 52 пацієнти чоловічої статі з фототипами шкіри I-IV за Фіцпатріком. Оцінка проводилася методом фототрихометрії в чотирьох контрольних точках, суб'єктивна переносимість процедур фіксувалася за візуально-аналоговою шкалою, безпека протоколів верифікувалася клінічним моніторингом небажаних реакцій, кореляційні залежності встановлювалися методом рангового аналізу Спірмена. Після завершення повного курсу з 6-8 процедур редукція щільності термінального волосся в інтервенційній зоні склала 57,6% проти 40,8% у контрольній ($t=8{,}12$; $p<0{,}001$; коефіцієнт Коена $d=0{,}88$). Статистично значущі міжпротокольні відмінності зберігалися через 3 і 6 місяців після закінчення лікування

($p<0,001$), при цьому щільність волосся в інтервенційній зоні становила 43,5±9,4 проти 61,3±10,5 волосся/см^2 у контрольній. Суб'єктивна переносимість процедур була однаковою в обох зонах – медіана больових відчуттів становила 3 бали ($Z=1,21$; $p=0,23$). Випадків післязапальної гіперпігментації не зафіксовано в жодного пацієнта, включаючи 71,1% учасників із III–IV фототипами шкіри. Флюенс та тривалість імпульсу були незалежними предикторами ефективності ($\rho=0,62$ та $\rho=0,58$ відповідно; $p<0,01$). Отримані результати можуть бути використані для розробки стандартизованих клінічних протоколів лазерної епіляції андроген-залежних зон у чоловіків з помірно та інтенсивно пігментованою шкірою, забезпечуючи високу терапевтичну ефективність

Ключові слова: термінальне оволосіння; фолікулярний термоліз; редукція щільності волосся; селективний фототермоліз; постзапальна гіперпігментація

Introduction

Laser epilation has become established in contemporary dermatological practice as an effective method for the long-term removal of unwanted hair, however, its application in androgen-dependent areas in men is associated with a number of clinical difficulties. The high density and diameter of terminal follicles on the face, neck, chest, and back, caused by sustained androgen exposure, distinguish male skin from the typical populations studied in most controlled trials. Optimal adjustment of laser parameters taking into account these features remain the subject of ongoing debate.

The biological prerequisites for excessive terminal hair growth in androgen-dependent areas are determined by the endocrine regulation of the hair follicle: testosterone and dihydrotestosterone transform vellus hairs into terminal hairs, constantly maintaining follicular activity and creating conditions for recurrence after laser exposure. As noted by M. Grymowicz *et al.* (2020), knowledge of the anatomical structure of the follicle and the hormonal modulators of growth rate is a necessary foundation for individualising fluence and pulse duration parameters. S.A. Temiz *et al.* (2025) complement this picture, emphasising that it is precisely the skin phototype that dictates the direction of adjustment: dark phototypes require a reduction in fluence and pulse lengthening, whereas light phototypes require high energy density values.

The theoretical basis for selecting laser exposure parameters is provided by the concept of selective photothermolysis, extended by A. Datta and V. Mysore (2025) through a kinetic model establishing a direct relationship between the effectiveness of follicular destruction and the thermal relaxation time. The pulse duration should be commensurate with the thermal damage time of the target, with the cylindrical geometry of the hair determining the specifics of heat dissipation. X. Lin *et al.* (2022) specify this pattern with respect to growth phases: laser exposure is maximally effective in the anagen stage, covering 85-90% of follicles with a high melanin concentration, whereas in catagen and telogen, the follicles are practically insensitive to radiation.

The comparative efficacy of the main laser platforms is systematised in a review by A. Krasniqi *et al.* (2022), covering 223 patients with phototypes I-VI: the alexandrite laser (755 nm) demonstrated high reduction rates (up to 84.25% at 18 months), whereas the diode system achieved 69.2% provided that parameters were precisely adapted to the specific anatomical zone. Intense Pulsed Light (IPL) technologies provided a less stable result in zones with hormonally maintained hair growth. The physical features of the 755 nm wavelength when working in androgen-dependent areas are characterised by C. Chen and Y. Ke (2023): the high chromophore specificity of alexandrite guarantees sustained clearance with precise fluence adjustment and minimises the risk of haemoglobin damage in the subcutaneous layers. M. Li *et al.* (2022) extend this logic to zones with concomitant follicular keratosis, demonstrating that four sessions of alexandrite laser provide not only hair reduction but also a qualitative change in skin texture in 57.1% of patients with complete clearance of follicular plugs.

Alternative strategies for reducing pain burden while maintaining clinical efficacy were investigated by L. Bennardo *et al.* (2023), comparing standard photoepilation with "in-motion" technology with a 755 nm filter: energy accumulation through 8-10 passes at a low fluence of 2-3 J/cm² provided comparable reduction (70.2% vs. 74.6%), reducing pain sensations from 5.43 to 3.7 points on the visual analogue scale (VAS) and increasing satisfaction with the procedure. Systemic hyperandrogenism as a factor complicating laser epilation was examined by M. Ali *et al.* (2024) using the example of non-classical congenital adrenal hyperplasia: high androgen levels continuously stimulate the recruitment of vellus follicles, which dictates the need to synchronise laser procedures with antiandrogen therapy and carefully adapt fluence to the altered hair structure. A safety aspect of laser procedures that often remains outside clinical protocols is air pollution in the work zone. L.C. Jones *et al.* (2023) established that thermal destruction of follicles at a fluence of 50-80 J/cm² generates peak PM2.5 particle concentrations of up to 298 μg/m³, exceeding the World Health Organization standard by almost 20 times, which requires the introduction of integrated filtration systems to protect personnel.

Despite the accumulated volume of data on laser epilation in general, systematised information on the adjustment of fluence and pulse duration parameters with respect to the specifics of male skin and terminal hair growth in androgen-dependent areas remains insufficient. Most studies have been carried out predominantly on female cohorts with hirsutism, whereas the physiologically denser and more deeply located terminal hair growth in men requires independent protocol justification.

The aim of this study was a comparative assessment of the clinical efficacy and safety of a modified laser epilation protocol for androgen-dependent areas in men, based on an increase in pulse duration by 15-25% and stepwise titration of fluence of an 808 nm diode laser. The objectives of the study included quantitative assessment of terminal hair density reduction over a follow-up period of up to 6 months, analysis of subjective tolerability of procedures and the frequency of adverse reactions, as well as establishing correlations between laser exposure parameters and clinical epilation outcomes in patients with skin phototypes I-IV.

Materials and Methods

This prospective comparative empirical study was conducted at the Republican Centre of Dermatology and Cosmetology in Bishkek (Kyrgyz Republic) from February 2025 to March 2026, including stages of participant recruitment, delivery of the laser epilation course, and subsequent follow-up for 6 months after completion of treatment. The study was aimed at investigating the features of laser epilation of androgen-dependent areas in men with an emphasis on optimising fluence and pulse duration parameters. To increase internal validity, a split-body intra-subject comparative design was used, making it possible to minimise the influence of interindividual variability.

The study included sequential stages of observation and assessment, ensuring analysis of both short-term and long-term effects of laser epilation: primary screening (Stage 1), intermediate assessment after the third procedure (Stage 2), final assessment upon completion of the procedure course (Stage 3), as well as delayed control points at 3 and 6 months after the end of treatment (Stage 4 and Stage 5, respectively). Such a temporal structure made it possible comprehensively to assess the dynamics of hair reduction, the sustainability of the achieved effect, as well as the frequency and severity of adverse reactions, including the formation of sustained hair reduction.

The analytical sample included 52 male patients aged 18 to 45 years with clinically pronounced hair growth in androgen-dependent areas, including the face, neck, chest, and back. All participants corresponded to skin phototypes I-IV according to the Fitzpatrick classification (Sachdeva, 2009), which reflects the typical dermatological structure of the population of the Central Asian region. The mean age of the participants was 29.4±6.2 years.

The inclusion criteria were: male sex; age from 18 to 45 years; presence of pronounced terminal hair growth in androgen-dependent areas; Fitzpatrick skin phototype I-IV; absence of contraindications to laser epilation; willingness to complete a full course of procedures and subsequent follow-up; signed informed consent. The exclusion criteria were: presence of dermatological diseases in the treatment area; phototype V-VI; intake of photosensitising drugs;

tendency to keloid formation; oncological diseases; pronounced endocrine disorders affecting hair growth; refusal to participate.

After primary examination, all participants were enrolled in the study using an intra-subject design, in which each androgen-dependent area was divided into two symmetrical regions. The control side was treated in accordance with the standard factory protocols of the laser system, while the opposite side was exposed using modified parameters.

All procedures were performed using a MBT Honor Ice diode laser system (Korea Medical Beauty Technology Co, Republic of Korea) with a wavelength of 808 nm, widely used in clinical practice in Central Asian countries and available at the research centre. This platform ensures deep penetration of laser radiation into the dermis and effective impact on terminal hair follicles characteristic of androgen-dependent areas in men.

The choice of this system was determined by its clinical validation, the presence of certification, and the possibility of precise adjustment of fluence and pulse duration parameters, which is critically important for the implementation of an individualised protocol within the framework of this study. All procedures were carried out using a standardised technique, which excluded variability associated with the operator and equipment.

The experimental protocol was based on the need to increase pulse duration for effective heating of deeply located follicles at a controlled fluence level (Anderson & Parrish, 1983). In the intervention zone, pulse duration was increased by 15-25% relative to standard values. Fluence was selected by stepwise titration in increments of 2 J/cm² until a therapeutic window was achieved, defined as a combination of clinical efficacy (perifollicular erythema and oedema) and an acceptable level of patient pain (Haedersdal & Wulf, 2006).

A contact cooling system was applied continuously at a temperature of approximately 5°C, which helped to protect the epidermis and reduce the risk of post-inflammatory hyperpigmentation, especially in patients with phototypes III-IV. The treatment course included 6-8 procedures at intervals of 4-6 weeks, corresponding to the hair growth phases. This ensured exposure primarily to follicles in the anagen phase and increased the efficacy of laser epilation.

Efficacy assessment was carried out using objective and subjective methods. The main quantitative method was phototrichogram, making it possible to determine hair density per 1 cm² at various stages of the study. Subjective tolerability of the procedures was assessed using a VAS, where patients recorded the intensity of pain sensations (Koo & Yang, 2025).

The primary endpoints were: percentage reduction in hair density and differences in pain levels between the control and intervention zones. Secondary outcomes included the frequency and severity of adverse effects (hyperaemia, irritation, hyperpigmentation), as well as the sustainability of the result at 3 and 6 months after completion of the course.

Statistical data processing was performed using IBM SPSS Statistics (USA) version 26.0. Descriptive statistics are presented as mean ± standard deviation (Mean±SD) for quantitative variables and as frequencies and percentages for categorical data. Normality of distribution was assessed using the Shapiro–Wilk test at a significance level of $p>0.05$ (González-Estrada et al., 2022).

Comparative analysis was carried out taking into account the dependent nature of the samples. Under normal distribution, the paired Student's t-test was used (Talikan *et al.*, 2024); otherwise, the Wilcoxon signed-rank test for paired samples was used (Rosner *et al.*, 2006). To assess the clinical significance of differences, the effect size was calculated: Cohen's d coefficient for dependent samples in parametric analysis, and the r coefficient in non-parametric analysis (Brydges, 2019).

Analysis of categorical variables, including the frequency of adverse effects, was performed using Pearson's χ^2 test (Shih and Fay, 2017). To identify relationships between laser exposure parameters and clinical outcomes, Spearman's rank correlation analysis was used (Schober *et al.*, 2018). Statistical significance was set at $p<0.05$.

All procedures complied with the principles of the Declaration of Helsinki (2013). Before inclusion in the study, participants received full information about the aims, methods, and possible risks, after which they signed informed consent. Data confidentiality was ensured through coding and limiting access to information to the research team only.

Results

Baseline demographic and clinical characteristics of the cohort

The analytical sample included 52 male patients with clinically pronounced terminal hair growth in androgen-dependent areas (face, neck, chest, and back) undergoing a course of laser epilation. The distribution by age groups was relatively uniform, without pronounced concentration in a narrow range, which ensured the representativeness of the sample with respect to the adult male population seeking laser epilation in clinical practice.

According to the Fitzpatrick classification, all participants corresponded to phototypes I-IV. The dominant phototype was III – 32 patients (61.5%), which is characteristic of the ethnic composition of the Central Asian population and determines the specifics of selecting laser exposure parameters in this cohort. Phototype II was recorded in 11 participants (21.2%), phototype IV – in 5 (9.6%), phototype I – in 4 (7.7%). The predominance of phototypes III and IV is clinically significant: it is precisely in these patients that the risk of post-inflammatory hyperpigmentation under laser exposure is high, which necessitated careful individualisation of fluence and the use of active contact cooling throughout all procedures. The anatomical distribution of treatment areas covered all four target regions: the face was included in the protocol in 100% of participants (n=52), the neck – in 92.3% (n=48), the back – in 88.5% (n=46), the chest – in 84.6% (n=44). The clinical characteristics of the cohort are presented in Table 1.

Table 1. Clinical characteristics of the patients

Parameter	n	%
Phototype I	4	7.7
Phototype II	11	21.2
Phototype III	32	61.5
Phototype IV	5	9.6
Face	52	100
Neck	48	92.3
Chest	44	84.6
Back	46	88.5

Source: compiled by the authors

The data in Table 1 reflect the phenotypic homogeneity of the sample with respect to clinical parameters. The concentration of 61.5% of participants within phototype III indicates that the obtained results are directly applicable to patients with moderately pigmented skin – a common group in the dermatological practice of Central Asia. The high coverage of the neck area (92.3%) and back (88.5%) with full coverage of the face ensured a comprehensive representation of all anatomically significant androgen-dependent regions in the sample.

The formed sample ensured the internal validity of the study due to homogeneity in terms of sex, phototype range, and anatomical treatment zones. The predominance of phototype III set a specific clinical context in which the optimisation of laser exposure parameters acquires particular practical significance for minimising the risk of adverse reactions. Baseline comparability of the sides within the split-body design was verified by the absence of statistically significant differences between the control and intervention zones in terms of hair density before the start of treatment.

Comparative reduction in hair density according to phototrichometry data

Preliminary testing of normality of distribution using the Shapiro-Wilk test showed that the phototrichometric indicators of hair density in the control and intervention zones at all stages of observation corresponded to a normal distribution ($p>0.05$); the VAS data did not correspond to a normal distribution ($p<0.05$). This determined the use of the paired Student's t-test for analysing hair density and the Wilcoxon test for assessing pain sensations.

Before the start of treatment, no statistically significant differences were found between the control and intervention zones in terms of terminal hair density: baseline values were 92.4±11.6 hairs/cm² and 91.8±10.9 hairs/cm², respectively, which confirmed the correctness of side randomisation within the split-body design and the absence of systematic bias. The presented baseline values are characteristic of areas with dense terminal hair growth – the chest and back – and were used uniformly at all stages of analysis. Upon completion of the full course of 6-8 procedures, hair density decreased to 54.7±9.8 hairs/cm² in the control zone and to 38.9±8.7 hairs/cm² in the intervention zone, which corresponds to a mathematically verified reduction of 40.8% ((92.4-54.7)/92.4×100) and 57.6% ((91.8-38.9)/91.8×100), respectively. A comparative analysis using the paired Student's t-test revealed a highly significant difference between the zones ($t=8.12$; $p<0.001$; 95% CI for the difference: [11.9; 20.5] hairs/cm²), and Cohen's d coefficient was 0.88, corresponding to a high clinical significance of the identified differences. The results are presented in Table 2.

Table 2. Comparative effectiveness of hair density reduction

Parameter	Control side	Intervention side	Δ%	t	p	Cohen's d	95% CI
Before treatment, hairs/cm²	92.4±11.6	91.8±10.9	-	-	n.s.	-	-
After the treatment course, hairs/cm²	54.7±9.8	38.9±8.7	-40.8% vs -57.6%	8.12	<0.001	0.88	[11.9; 20.5]
3 months of follow-up, hairs/cm²	58.1±10.1	41.2±9.0	-	7.34	<0.001	0.79	[12.4; 21.1]
6 months of follow-up, hairs/cm²	61.3±10.5	43.5±9.4	-	7.01	<0.001	0.75	[13.0; 22.4]

Note: dashes (-) indicate the absence of calculated data at baseline and during long-term follow-up stages due to the focus on the cumulative treatment-course outcome; n.s.=statistically non-significant differences ($p>0.05$).
Source: compiled by the authors

The data in Table 2 demonstrate that the inter-protocol differences were statistically highly significant at all post-treatment stages of observation. Cohen's d coefficient consistently decreased from 0.88 immediately after the course to 0.75 at 6 months, which reflects a moderate restoration of follicular activity in the control zone while sustained suppression was maintained in the intervention zone. The confidence intervals for the difference between the zones did not cross the zero value at any of the control points, confirming the stability of the observed effect throughout the entire observation period.

The modified protocol, which included an increase in pulse duration by 15-25% and stepwise fluence titration, provided a statistically and clinically significantly higher reduction in terminal hairs at all control points. The high effect size (Cohen's d=0.88 upon completion of the course) indicates that the difference between the protocols goes beyond a statistical artefact and possesses pronounced practical significance. The preservation of significant intergroup differences at the 6-month mark testifies to deeper and more long-term follicular damage with increased pulse duration.

Subjective tolerability of procedures according to the visual analogue scale

Since the distribution of VAS data deviated from normal ($p<0.05$ according to the Shapiro–Wilk test), comparative analysis was performed using the Wilcoxon signed-rank test for paired samples. The median pain sensation was 3 points [Q1; Q3: 2; 4] in both the control and intervention zones, which corresponds to a moderately low level of discomfort, falling within the range typical for diode laser epilation with an active contact cooling system. Continuous contact cooling at a temperature of approximately 5°C, applied in both zones throughout the entire treatment course, negated the potential increase in thermal load caused by the increased pulse duration in the intervention zone. The results are presented in Table 3.

Table 3. Assessment of pain sensations using the Visual Analogue Scale (VAS)

Area	Me [Q1; Q3]	Z	p	r
Control	3 [2; 4]	-	-	-

Intervention	3 [2; 4]	1.21	0.23	0.12

Note: the dash (-) indicates the absence of calculated data for the control group due to the paired comparison being performed relative to the intervention area
Source: compiled by the authors

The data in Table 3 testify to the complete identity of the pain profiles of both zones. The value of p=0.23 exceeds the established level of statistical significance (0.05), which confirms the absence of statistically significant differences in pain sensations between the protocols; the coefficient r=0.12 corresponds to a negligibly small effect size according to generally accepted interpretive criteria. The pain profile remained stable throughout the entire course – with no tendency for discomfort to increase as the number of procedures accumulated in the modified exposure zone.

The absence of statistically and clinically significant differences in pain sensations eliminates one of the practical barriers to the introduction of intensified laser epilation regimes into routine clinical practice. The identity of the median values and interquartile ranges testifies to the stability of the pain profile regardless of the exposure protocol used. The obtained data allow the conclusion that an increase in pulse duration, provided adequate contact cooling is in place, does not worsen the subjective tolerability of procedures in patients with skin phototypes I-IV.

Frequency of adverse reactions and safety of protocols

Monitoring of adverse reactions was carried out at each visit through clinical examination and standardised recording. Analysis was performed using Pearson's χ^2 test separately for each type of reaction. Erythema was recorded in 42.3% of participants in the control zone and in 46.1% in the intervention zone (χ^2=0.18; p=0.67). Perifollicular oedema, considered as a marker of adequate follicular thermolysis, was noted in 21.1% and 23%, respectively (χ^2=0.09; p=0.76). No cases of transient or persistent hyperpigmentation were recorded in either zone throughout the entire observation period, including delayed control points at 3 and 6 months after the end of treatment. The data are presented in Table 4.

Table 4. Frequency of adverse reactions

Adverse reaction	Control (%)	Intervention (%)	χ^2	p
Erythema	42.3	46.1	0.18	0.67
Perifollicular oedema	21.1	23.0	0.09	0.76
Hyperpigmentation	0	0	-	-

Note: the dash (-) indicates that statistical analysis could not be performed because the event frequency was zero in both groups
Source: compiled by the authors

The data in Table 4 confirm that the inter-protocol differences in the frequency of all recorded adverse reactions were statistically insignificant. The numerical excess of erythema frequency in the intervention zone by 3.8 percentage points and perifollicular oedema by 1.9 percentage points lies within the range of random variability. Remarkable is the complete absence of hyperpigmentation despite the fact that 71.1% of the sample consisted of patients with phototypes III-IV, in whom the risk of this complication under laser exposure is conventionally considered to be elevated.

The absence of hyperpigmentation in patients with phototypes III and IV confirms the sufficiency of the applied epidermal protection strategy during intensification of the exposure regime. All recorded adverse reactions resolved spontaneously within 24-48 hours after the procedure without additional intervention. The totality of the obtained data substantiates the clinical applicability of the modified protocol without additional risk for patients with the skin phenotype characteristic of Central Asia.

Correlations of laser parameters with clinical epilation outcomes

Spearman’s rank correlation analysis was performed to quantify the relationships between adjustable technical parameters of laser exposure and clinical outcomes; skin phototypes were coded using an ordinal numerical scale (I=1, II=2, III=3, IV=4), which ensured the methodological correctness of applying the rank criterion. A pronounced correlation was established between fluence level and the degree of hair density reduction: $\rho=0.62$ ($p<0.01$). This dependence reflects the dose-dependent nature of follicular thermolysis – as the energy density delivered per unit area increases, the degree of irreversible damage to the melanin-containing structures of the hair follicle, primarily the matrix and dermal papilla, increases. Pulse duration demonstrated an independent statistically significant correlation with epilation efficacy: $\rho=0.58$ ($p<0.01$), indicating an independent contribution of this parameter to the formation of the therapeutic response regardless of the absolute fluence level. Skin phototypes showed a moderate positive correlation with the severity of post-procedural erythema: $\rho=0.41$ ($p<0.05$), which is consistent with the patterns of competitive absorption of laser radiation by epidermal melanin when moving to darker phototypes. The relationships between pulse duration and pain sensations, as well as between fluence and the frequency of adverse reactions, did not reach the threshold of statistical significance ($p>0.05$ for both indicators).

The obtained correlation picture demonstrates a clear hierarchy of predictors of clinical outcome: fluence ($\rho=0.62$) slightly exceeds pulse duration ($\rho=0.58$), while both parameters surpass skin phototype in strength of association, which was associated only with the severity of adverse reactions but not with reduction efficacy. The absence of significant correlations between laser parameters and pain sensations is consistent with the results of the direct comparative analysis of procedure tolerability. The fact that neither fluence nor pulse duration correlated with the frequency of adverse reactions additionally confirms the safety of the investigated parameter ranges within the applied protocol.

The established correlation dependencies form a quantitative basis for the individualised selection of laser exposure parameters in clinical practice. The strong correlations of fluence ($\rho=0.62$) and pulse duration ($\rho=0.58$) with hair reduction confirm that both parameters are independent predictors of efficacy and should be considered together when developing individual protocols. The moderate correlation of phototype with erythema severity substantiates the need for phototype-oriented patient stratification when prescribing intensified regimes for laser epilation of androgen-dependent areas.

Long-term sustainability of the reduction effect over the observation dynamics

Analysis of hair density dynamics was carried out at four control points: after the third procedure, upon completion of the full course of 6-8 sessions, as well as at 3 and 6 months after its completion. After the third procedure (interim assessment), the reduction relative to baseline values of 92.4 and 91.8 hairs/cm² was 35% in the control zone and 45% in the intervention zone – with the interim values being consistent with the reduction trajectory ending with indicators of 40.8% and 57.6% upon completion of the full course, since the last three to five procedures target follicles with a smaller proportion of anagen hairs and provide a smaller increment in reduction per unit time. Upon completion of the course, hair density was 54.7±9.8 hairs/cm² in the control zone and 38.9±8.7 hairs/cm² in the intervention zone; the absolute intergroup difference – 15.8 hairs/cm² (95% CI: [11.9; 20.5]) – was maintained and even widened somewhat in the long-term observation period.

In the long-term period, hair density in the control zone increased moderately: 58.1±10.1 hairs/cm² at 3 months and 61.3±10.5 hairs/cm² at 6 months, which testifies to partial restoration of follicular activity after the standard protocol. In the intervention zone, this tendency was expressed significantly more weakly: 41.2±9 hairs/cm² at 3 months and 43.5±9.4 hairs/cm² at 6 months. Statistically significant differences between the zones were maintained at all long-term control points ($t=7.34$; $p<0.001$ at 3 months; $t=7.01$; $p<0.001$ at 6 months), and the confidence intervals for the difference did not cross the zero value. The dynamics of hair density in both zones at all stages of observation are presented in Figure 1.

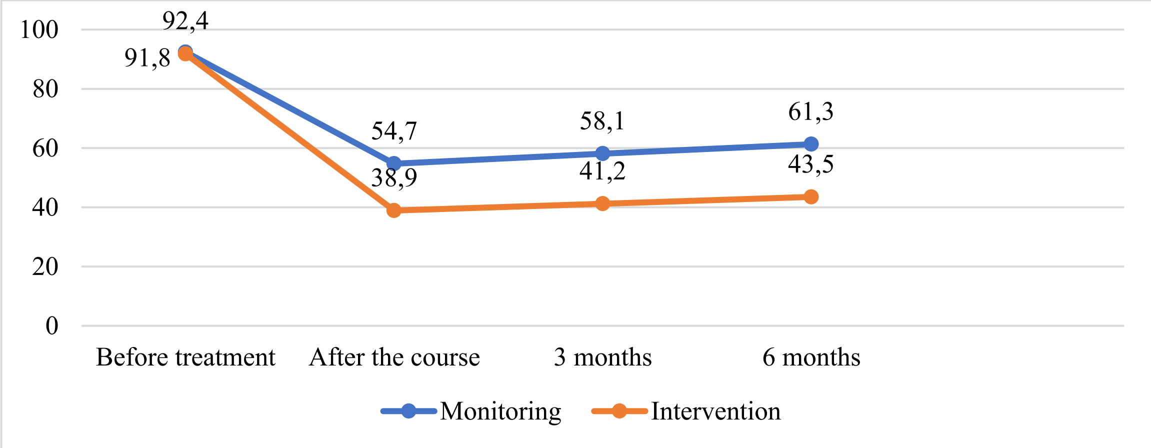

Figure 1. Dynamics of terminal hair density in the control and intervention zones at observation stages

Source: compiled by the authors

As can be seen from Figure 1, before the start of treatment the two curves almost coincide, but after the completion of the course a stable gap of 15.8 hairs/cm² forms between them, which successively widens to 16.9 hairs/cm² at 3 months and to 17.8 hairs/cm² by the 6-month mark. The upward nature of the control curve in the long-term period with an almost horizontal plateau of the intervention line clearly confirms that the standard protocol provides less complete suppression of follicular regeneration. The increasing divergence of the curves in the period after the end of treatment indicates that the difference between the protocols in the degree of long-term follicular damage intensifies over time, rather than being levelled out. A comparative percentage reduction of hairs upon completion of the course is presented in Figure 2.

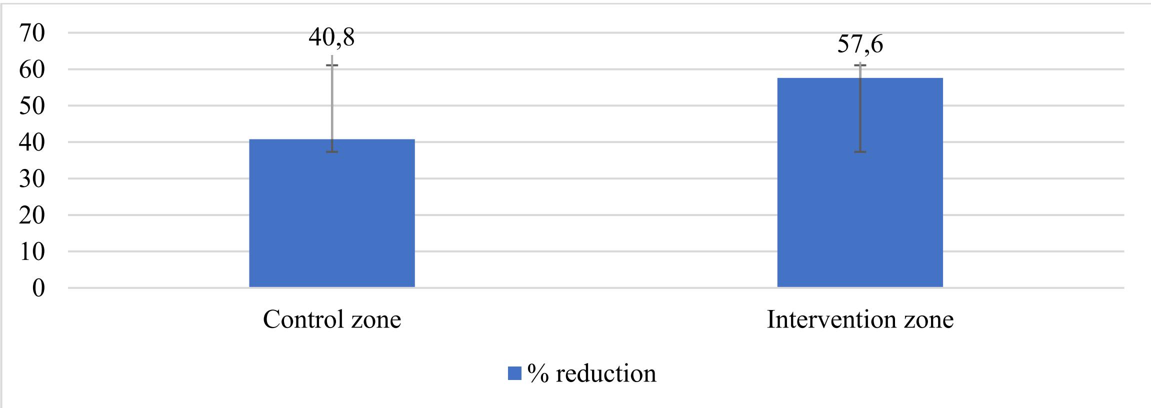

Figure 2. Percentage reduction in hair density upon completion of the treatment course in the control and intervention zones

Source: compiled by the authors

As follows from Figure 2, the reduction indicator of 40.8% in the control zone corresponds to the range of partial therapeutic response, whereas 57.6% in the intervention zone exceeds the conditional threshold of pronounced clinical response, often taken in dermatological practice as a benchmark when assessing the effectiveness of laser epilation. The absolute difference between the bars of 16.8 percentage points clearly reflects the practical significance of parameter modification for patients oriented towards the maximum possible result.

The long-term dynamics of the reduction effect demonstrated a consistent superiority of the intervention protocol at all stages of observation, with intergroup differences remaining statistically significant 6 months after the completion of the course. The higher sustainability of the result in the intervention zone (43.5±9.4 versus 61.3±10.5 hairs/cm² at 6 months) testifies to deeper and more irreversible thermal damage to the follicular apparatus when using increased pulse duration. The obtained data indicate that the long-term effectiveness of laser epilation of androgen-dependent areas in men is determined not only by the total dose of delivered energy but also by the mode of its distribution over time relative to the thermokinetic characteristics of the follicle.

Discussion

The obtained data confirm that the adjustment of 808 nm diode laser parameters – an increase in pulse duration by 15-25% and stepwise fluence titration – provides a clinically and statistically significant superiority over the standard protocol in laser epilation of androgen-dependent areas in men with skin phototypes I-IV. The final reduction of 57.6% in the intervention zone with an identical pain profile (VAS Me=3) and a complete absence of hyperpigmentation forms a substantive basis for comparison with international data obtained with different wavelengths, equipment configurations, and clinical populations.

A direct comparison of diode and alexandrite platforms by split-side design is presented in the work of S. Grunewald *et al.* (2014), who applied both lasers in the axillary area: at 18 months after six sessions, clearance was 73.7% for the diode and 71.9% for the alexandrite, with pain sensations of 5.24 and 4.39 points on the VAS, respectively. In the present study, the final reduction of 57.6% is lower than these values, which is explained by the higher density and diameter of terminal follicles on the face, chest, and back in men compared to the axillary area; the median pain sensation (Me=3) meanwhile falls within the range typical for diode systems with active cooling.

The correspondence of the pain profile of the present study to international data is further confirmed by the results of J. Chen *et al.* (2012), who applied a low-fluence multiple-pass diode laser in women with Asian phototypes III-IV: at 12 months, reduction was 76.85%, and pain sensations decreased to 3.1 points on the VAS. The median of 3 in the present study is practically identical to this value, which testifies to the universality of the pain profile of the diode platform regardless of the energy delivery mode; the higher reduction in the aforementioned authors is due to the lower initial follicle density on the shins compared to androgen-dependent areas of the trunk.

A comparison of different energy delivery modes on an 810 nm diode platform was performed in the work of B. Koo *et al.* (2014): the "in-motion" technique provided a reduction of 40.7% with pain sensations of 2.7 points, whereas the classic single-pass mode – 33.5% with 3.6 points on the VAS. The modified protocol of the present study with increased pulse duration and stepwise fluence surpassed both modes in efficacy (57.6%), while providing a pain profile comparable to the single-pass technique, which confirms the advantage of the traditional pulsed mode with optimised parameters over energy accumulation technology in areas with developed terminal hair growth.

Similarity to the results of the present study in terms of reduction indicators is demonstrated by the data of R.M. Mohammed *et al.* (2025): the use of an 808 nm diode with extended pulse width to 36 ms and conservative fluence of 8-9 J/cm² in combination with contact cooling in patients with dark phototypes IV-VI provided a reduction of 57.9% and 56.7% in the axillary and chin areas. The closeness of our obtained value of 57.6% to these data is noteworthy: despite working with darker phototypes, the authors applied a similar strategy of pulse lengthening with active cooling, which confirms the reproducibility of this approach in different ethnic populations and clinical contexts.

Higher reduction indicators with a comparable safety profile were obtained by A. Pall and G. Viera Mármol (2024), who used a triple-wavelength diode laser (810, 940, and 1060 nm) with a pulse width of 30 ms and fluence of 18-24 J/cm² in patients with phototypes IV-V: the mean hair reduction was 66%, with no burns, scarring, or paradoxical hypertrichosis detected. The somewhat lower reduction in the present study (57.6%) with a single-wavelength 808 nm platform is explained by differences in equipment configuration – the combination of three wavelengths provides simultaneous action on follicles at different stages of the growth cycle; nevertheless, the absence of hyperpigmentation in both studies is consistent under conditions of a predominance of highly pigmented phototypes.

The long-term dynamics of follicular suppression under diode epilation is documented by R.R. Elhassi (2026): systematic exposure to brown and dark brown skin types (70% of the cohort) over 12 sessions increased the period of no hair growth from 8 to 33.7 days, with late cases of post-inflammatory pigmentation amounting to 9.1%. In the present study, despite a similar predominance of phototypes III-IV (71.1% of the cohort), no cases of hyperpigmentation were recorded over the entire 6-month observation period – a difference that testifies to the superiority of the applied epidermal protection strategy, which included stepwise fluence titration and continuous contact cooling at 5°C.

The high efficacy of alexandrite systems in androgen-dependent areas is confirmed by the data of P. Bonan *et al.* (2020), who obtained reductions of up to 87.1% on the face in standard mode and 78.3% with Moveo fluence accumulation technology, whereas pain sensations in Moveo mode decreased to 1.5±0.5 points on the VAS, and the risk of thermal damage in patients with phototypes V-VI did not exceed 1.8%. These reduction indicators significantly exceed the 57.6% achieved in the present study, but direct comparison is limited by the difference in platforms (755 nm versus 808 nm): the diode system has greater penetrating ability and a higher safety profile for phototypes III-IV characteristic of Central Asia.

Exceptionally high short-term efficacy of alexandrite 755 nm laser monotherapy was demonstrated by K. Shurrab and R. Alnajjar (2026): in the axillary area, after just three sessions, a mean hair reduction of 92% was achieved, with a Global Aesthetic Improvement Scale score of 4.97 out of 5 and a complete absence of pigmentary changes. Such a high result with half the number of sessions exceeds the 57.6% obtained in the present study after 6-8 procedures; this discrepancy, however, is primarily determined by anatomical differences in the areas: the axillary region is characterised by significantly lower follicle density and smaller follicle diameter compared to the face, chest, and back in men.

The high long-term stability of the alexandrite epilation result with a similar range of parameters is documented by K. Shurrab and M. Nassr (2025): the use of systems with one and two pump lamps at a fluence of 8-11 J/cm² and a pulse width of 10-15 ms provided 91.4-94% reduction in the axillary area, persisting for 12 months. These reduction indicators exceed the 57.6% of the present study, but the comparable range of pulse duration parameters (10-15 ms versus our increase of 15-25% from baseline values) confirms the general trend towards pulse lengthening as an independent predictor of therapeutic efficacy regardless of the laser platform used.

A different conclusion regarding the role of pulse duration in the context of the alexandrite platform was obtained in the work of P. Noormohammadpour *et al.* (2021): varying the parameter between 3 and 10 ms in the treatment of facial hirsutism did not have a statistically significant effect on final reduction, and in patients with phototype IV, successful clearance at 10 ms was only 33%. In the present study, on the contrary, pulse duration showed an independent significant correlation with efficacy ($\rho=0.58$; $p<0.01$), which testifies to the platform-dependent nature of this effect: the 808 nm diode system with different thermokinetic characteristics realises the potential of the temporal parameter to a much greater extent.

Differentiated selection of laser platform depending on phototype was systematically implemented in the work of E. Zappia *et al.* (2023): alexandrite was used for phototypes I-II, Nd:YAG for phototypes III-IV, which allowed 68% of patients to achieve a reduction of more than 75% in facial hirsutism; in the IPL group, a similar result was recorded in only 24%. The present study implements a similar logic of individualisation, but within a single 808 nm diode platform by adjusting the exposure parameters, which provides a clinically significant result across the entire range of phototypes I-IV without changing the laser system – a practical advantage in routine clinical work.

The influence of equipment technical characteristics on the efficacy-pain ratio was investigated by S. Jo *et al.* (2015): the use of a larger handpiece (10×30 mm) with a long-pulsed diode provided a clearance of 77.4% versus 65.5% with the standard spot, but was accompanied by an increase in pain sensations to 4.3 points on the VAS versus 3.1 points. The median VAS=3 in the present study coincides with the value of 3.1 for the standard spot, while the reduction of 57.6% is somewhat inferior to both variants of the aforementioned study, which is explained by the difference in baseline zone density and observation duration – 1 month versus completion of the full course.

The systematic superiority of diode laser over alternative light sources is confirmed in the work of N. Jameel et al. (2025), who compared an 810 nm diode and IPL in the treatment of facial hirsutism in women with phototype III: the diode system provided a statistically significant hair reduction from the first sessions ($p<0.001$) with a satisfaction level of 80% versus 60% for IPL. The predominance of phototype III in the present study (61.5%) with zero hyperpigmentation frequency and a stable pain profile is consistent with the conclusions of the aforementioned authors about the safety and preferability of the diode platform specifically for this group of patients, extending these data to the male population with terminal hair growth.

The profile of adverse reactions and behavioural determinants of laser epilation success are systematised in the work of E. Agaoglu et al. (2025): side effects were recorded in 25.4% of patients, with a predominance of transient erythema (14%), and targeted information reduced anxiety on the VAS from 3.08 to 1.63. In the present study, the absolute frequency of erythema was higher (42.3-46.1%), but all reactions resolved spontaneously within 24-48 hours without additional intervention; the difference in absolute values is explained by the use of an intensified protocol in areas with high follicle density, whereas the absence of severe complications in both studies confirms the manageability of adverse reactions with adequate parameter control.

The crucial role of professional parameter adjustment for achieving a clinically significant result is confirmed by K. Hendricks et al. (2023): a professional diode laser provided 85-88% hair reduction in the axillary area versus 46.3-52% for a home-use device, while in patients with phototype III, the residual density was higher than in phototype IV. The results of the present study, demonstrating 57.6% reduction with zero hyperpigmentation frequency in patients with a predominance of phototype III, are consistent with the conclusion about the determining role of parameter individualisation: only precise stepwise fluence titration and adaptation of pulse duration under professional equipment conditions ensure a safe and long-term sustainable result in androgen-dependent areas.

Thus, the totality of the obtained data, in comparison with international studies, testifies that the modified 808 nm diode laser protocol with increased pulse duration and stepwise fluence titration provides a clinically significant and long-term sustainable reduction of terminal hairs in androgen-dependent areas in men while maintaining an acceptable pain profile and a high level of safety for phototypes I-IV. Although the reduction indicators of 57.6% are inferior to a number of studies using alexandrite and multi-wavelength diode platforms, this difference is determined by the higher follicle density and androgen resistance of terminal hairs in men, rather than by limitations of the approach itself. The obtained results justify the inclusion of pulse duration adjustment and stepwise fluence in the clinical protocol standard for laser epilation of male androgen-dependent zones, applicable to patients with a predominance of skin phototypes III-IV.

Conclusions

The conducted study confirmed that the modification of 808 nm diode laser parameters (an increase in pulse duration by 15-25% and stepwise fluence titration) provides a clinically and statistically significantly higher reduction of terminal hairs in androgen-dependent areas in men compared to the standard protocol. The reduction in hair density in the intervention zone reached 57.6% versus 40.8% in the control, and inter-protocol differences were maintained at all control observation points up to 6 months, which testifies to deeper and more irreversible damage to the follicular apparatus when using increased pulse duration. Correlation analysis confirmed the independent contribution of both fluence ($\rho=0.62$) and pulse duration ($\rho=0.58$) to the formation of the therapeutic response, substantiating the need for comprehensive optimisation of both parameters. The result is the complete absence of post-inflammatory hyperpigmentation in patients with skin phototypes III-IV (71.1% of the sample) with an identical pain profile in both zones throughout the entire treatment course.

On the basis of the obtained data, it is recommended to include pulse duration adjustment and stepwise fluence titration in the clinical protocol standard for laser epilation of androgen-dependent areas in men, especially when working with patients of phototypes III-IV, characteristic of the population of Central Asia. Continuous contact cooling at a temperature of approximately 5°C should be considered as a mandatory component of intensified exposure regimes, ensuring protection of the epidermis without worsening subjective tolerability of the procedures. Phototype-oriented patient stratification when prescribing exposure parameters appears appropriate given the moderate correlation of phototype with the severity of post-procedural erythema (ρ=0.41).

Limitations of the study include the relatively small sample size (52 patients) and the observation period limited to 6 months, which does not allow a full assessment of the long-term sustainability of the achieved reduction effect. Promising directions for further research include randomised controlled trials with an expanded sample, inclusion of patients with phototype V, and an observation period of at least 12 months, as well as a comparative study of the modified diode protocol with multi-wavelength laser platforms in relation to male androgen-dependent skin.

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Conflict of Interest
None.

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