OPTIMIZED CORRECTION OF AGE-RELATED SKIN CHANGES CONSIDERING PATIENT HORMONAL STATUS AND HIGH-FREQUENCY ULTRASOUND DIAGNOSTIC DATA

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Abstract This study aims to develop and substantiate an optimized algorithm for the correction of age-related skin changes, based on an integrated approach that accounts for the patient's hormonal status together with high-frequency ultrasound scanning data. The influence of estradiol, thyroid-stimulating hormone (TSH), free thyroxine (FT4), and prolactin levels on the dynamics of structural dermal changes was analyzed. The proposed methodology employs corneometry and cutometry to objectively assess the skin's viscoelastic properties, along with high-frequency ultrasound imaging to evaluate tissue thickness and acoustic density. The results demonstrate that personalized therapy, adjusted according to individual endocrine parameters and objective instrumental diagnostic data, achieves a more pronounced and sustained rejuvenating effect compared with standard protocols. The study highlights the importance of integrating dermatological and endocrinological data to enhance the efficacy of aesthetic procedures.

Keywords age-related skin changes; hormonal status; estradiol; high-frequency ultrasound; corneometry; cutometry; skin viscoelastic properties; acoustic density; dermatology; aesthetic medicine; personalized therapy; skin rejuvenation; endocrine profile; correction methods; skin diagnostics.

Introduction

Age-related skin changes represent a complex, multifactorial process determined by both external influences and internal biological changes in the body. A key role in this process is played by hormonal fluctuations, particularly during the peri- and postmenopausal periods, which substantially affect collagen synthesis and dermal hydration [1]. Contemporary aesthetic medicine calls for a shift from standardized protocols toward personalized correction strategies grounded in objective data [2]. The aim of this study is to substantiate an optimized approach to skin rejuvenation that integrates assessment of the hormonal profile — including estradiol, TSH, FT4, and prolactin — with instrumental diagnostic data. High-frequency ultrasound scanning offers new opportunities for visualizing microstructural skin changes, enabling assessment of skin thickness and acoustic density before and after therapeutic procedures [3]. The relevance of this topic stems from the need to improve the predictability of aesthetic intervention outcomes by accounting for the patient's physiological state. Implementation of this algorithm makes it possible to identify the pathogenetic features of skin aging specific to each patient and to select the most effective correction methods while excluding unnecessary or inappropriate manipulations. This study is aimed at building an evidence base for introducing high-frequency ultrasound methods into dermatocosmetology practice for the quantitative evaluation of aesthetic correction efficacy in relation to endocrine status.

Literature Review

The influence of hormonal status on skin condition has been the subject of numerous recent studies confirming a correlation between declining estrogen levels and the progression of atrophic skin changes [4]. Research indicates that estradiol plays a key role in regulating keratinocyte proliferation and the synthesis of dermal extracellular matrix components [5]. At the same time, thyroid function, reflected in TSH and FT4 levels, significantly affects metabolic processes in the skin, including sebum

production and regeneration [6]. Prolactin, in turn, is involved in regulating immune response and barrier function, which is also considered in the context of age-related skin changes [7]. Methods for assessing viscoelastic properties, such as cutometry, are widely recognized in dermatology as reliable tools for the quantitative analysis of skin elasticity [8]. Corneometry, which assesses stratum corneum hydration, complements the clinical picture by providing insight into skin barrier integrity [9]. High-frequency ultrasound, with resolution sufficient to visualize individual skin layers, is recognized as the most promising method for evaluating dermal architecture and the acoustic density of collagen fibers [10]. A review of the literature reveals the absence of a unified approach integrating endocrine status and high-frequency ultrasonography as predictors of correction success, underscoring the need for the present study.

Methodology

The study methodology is based on a systemic approach to assessing skin condition through the integration of laboratory and instrumental data. Classical methods of clinical assessment served as the primary comparator, benchmarked against results obtained through high-frequency ultrasound, corneometry, and cutometry. The developed algorithm was expected to improve the accuracy of correction outcome prediction by 20–30% relative to conventional methods. Statistical significance criteria were applied to exclude the influence of random factors on the evaluation of the proposed strategy's efficacy.

Materials and Methods

The study was conducted at a clinical center involving 172 patients, stratified into groups according to the severity of age-related skin changes and endocrine profile.

Table 1. Distribution of patients by severity of age-related skin changes according to the S.N. Potapova classification (n=172).

Severity grade	Group I (n=58)	Group II (n=57)	Group III (n=57)
Grade I	24	22	21
Grade II	20	21	20
Grade III	10	11	12
Grade IV	4	3	4

Each patient's hormonal status was determined by analysis of venous blood for estradiol, TSH, FT4, and prolactin levels, performed at an accredited laboratory. Instrumental assessment included corneometry to measure stratum corneum hydration and cutometry to determine the dermis's viscoelastic parameters, such as the elasticity modulus and the capacity for recovery after deformation.

Table 2. Distribution of patients by aging morphotype according to the I.I. Kolgunenko classification (n=172).

Aging morphotype	Total (n=172)	Group I (n=58)	Group II (n=57)	Group III (n=57)
Fatigued type	27	12	8	7
Fine-wrinkled type	32	12	10	10
Deformational type	58	19	18	21
Muscular type	12	5	4	3
Combined type	43	15	14	14

High-frequency ultrasound examination was performed using a 20–50 MHz transducer, ensuring high-precision visualization of skin layers. Parameters measured included total epidermal and dermal thickness, as well as mean acoustic density, reflecting the condition of the collagen framework. All measurements were taken at standardized, symmetrical facial points before treatment, at the midpoint of the course, and three months after its completion. The correction course for each patient group was individually tailored based on identified hormonal deviations and ultrasound findings, combining device-based methods with specialized topical agents. Statistical analysis was performed

using parametric and non-parametric methods, ensuring the reliability of conclusions at a significance level below 0.05. Standardization of measurement procedures minimized error and ensured comparability of data across the different age categories of patients enrolled in the study.

Analysis of the efficacy of the developed correction algorithm, based on the combined use of microneedle radiofrequency treatment, thulium laser, and topical resveratrol, revealed pronounced positive dynamics in structural and functional skin parameters across all study groups. The integration of these methods not only achieved a visually significant rejuvenating effect but also objectively confirmed dermal matrix regeneration through instrumental diagnostic methods.

According to follow-up examination three months after completion of therapy, dermal acoustic density (DAD), measured by high-frequency ultrasound, showed a statistically significant increase across all groups. In patients receiving combined therapy, the mean DAD value increased by 25–28% relative to baseline, indicating active neocollagenesis and restoration of collagen structure density. The greatest positive dynamics were observed in patients with initially low hormonal status, confirming the efficacy of targeted resveratrol delivery through the microchannels created by the thulium laser.

Table 3. Facial skin hydration in women by anatomical zone and age group (mean ± SD, arbitrary units).

Site	Age 30–45 (normal)	Age 30–45 (below normal)	Age 46+ (normal)	Age 46+ (below normal)
Forehead	58.9±8.6	45.1±2.1	54.2±5.4	41.2±2.8
Zygomatic area (right)	58.6±10.0	43.7±2.3	53.5±4.5	40.5±3.0
Zygomatic area (left)	58.4±9.7	44.1±2.4	53.2±4.8	40.6±3.2
Nasolabial zone	57.6±8.2	44.8±1.9	52.1±5.1	39.5±2.5
Chin	57.5±7.9	45.4±1.5	52.9±4.7	40.2±2.2

Corneometry data also confirmed the high efficacy of the proposed protocol in restoring epidermal barrier function. Stratum corneum hydration increased by an average of 30–35% after completion of the course in patients with an initially pronounced moisture deficit. The statistically significant improvement in hydration parameters indicates that comprehensive correction affects not only deep dermal structures but also promotes normalization of keratinization and restoration of the skin surface's water–lipid balance.

Assessment of elasticity parameters by cutometry revealed pronounced restoration of soft tissue elasticity. The overall elasticity parameter (R2) showed a 20–22% increase in groups receiving combined device-based treatment, correlating with a clinical reduction in nasolabial fold depth and improved contouring of the lower third of the face. Notably, the results achieved remained highly stable throughout the entire observation period, indicating the durability of dermal restructuring processes initiated by the proposed algorithm.

Clinical outcomes assessed using the Global Aesthetic Improvement Scale (GAIS) showed a high degree of patient satisfaction with the results achieved. The majority of participants (more than 85%) reported a marked improvement in skin quality, increased tone, and a visible reduction in signs of skin aging. Comparative analysis demonstrated that combined therapy offers a significant advantage over monotherapy, providing more pronounced and prolonged improvement in tissue structural characteristics. Thus, the developed algorithm for optimized correction, based on the integration of endocrine status and high-frequency ultrasound diagnostic data, represents an effective and safe method for achieving predictable and sustained outcomes in aesthetic dermatology.

Results

Analysis of the data revealed a direct relationship between estradiol level and dermal acoustic density, as measured by high-frequency ultrasound. Patients with estrogen deficiency showed a 15% reduction in acoustic density compared with the control group, which correlated clinically with loss of

skin tone and elasticity, as confirmed by cutometry data. Application of the optimized correction protocol, including deficiency correction and targeted device-based stimulation, achieved a 25% increase in acoustic density by the end of the 3-month observation period. Hydration levels, measured by corneometry, increased by an average of 30% in patients with initially low baseline values, indicating improved skin barrier function. TSH and FT4 levels within reference ranges proved critical for achieving a sustained response to aesthetic procedures. Patients with abnormal prolactin levels showed less pronounced recovery of viscoelastic properties, indicating the need to correct this factor prior to initiating intensive device-based interventions. Statistical analysis confirmed the efficacy of individualized treatment planning based on the proposed algorithm.

Discussion

The study results confirm the hypothesis that hormonal status is a determining factor in the efficacy of aesthetic correction methods. Comparison with previous research underscores the importance of individualizing treatment approaches. High-frequency ultrasound enables visualization of changes that are not detectable by standard clinical examination, making it an indispensable tool in contemporary practice. Notably, achieving acoustic density levels characteristic of younger skin is not possible without controlling endocrine processes, as confirmed by the correlation between estradiol levels and collagen framework status. A limitation of this study is the need for further follow-up to assess the long-term stability of results; nevertheless, the data obtained already support recommending the integration of the proposed algorithm into patient management protocols.

Conclusions

This study demonstrates the high efficacy of an optimized approach to correcting age-related skin changes that integrates the endocrine profile with high-frequency ultrasound diagnostic data. Assessment of estradiol, TSH, FT4, and prolactin levels is an essential requirement for formulating a personalized treatment plan. Corneometry and cutometry provide objective assessment of the skin's functional status, while high-frequency ultrasound allows quantitative evaluation of changes in its structure and density. The proposed method has proven capable of enhancing the effectiveness of rejuvenation procedures while ensuring the safety and predictability of the therapeutic process. Further development of this field is envisioned through the automation of ultrasound image analysis using machine learning methods, enabling even more precise prediction of correction outcomes. Thus, the systemic integration of laboratory data and high-precision instrumental methods represents the most promising direction for the future development of aesthetic dermatology.

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