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# Predictors of the effectiveness of multimodal noninvasive facial rejuvenation: a conceptual model incorporating skin condition, soft-tissue characteristics, edema, and muscle tone

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## Abstract

Current noninvasive facial rejuvenation methods can target different tissue layers; however, treatment outcomes vary considerably even when comparable protocols are used. Accordingly, predicting treatment response based on patients' baseline characteristics represents a promising direction. The aim of this study is to systematize potential predictors of the effectiveness of multimodal noninvasive facial rejuvenation and to develop a conceptual multifactorial model for predicting treatment response. The study materials comprised clinical studies and review articles addressing age-related facial changes, radiofrequency technologies, microfocused ultrasound, neuromuscular stimulation, midfacial edema, and methods for assessing aesthetic outcomes. Comparative analysis, systematization, and conceptual modeling were employed. Four groups of potential predictors were identified: skin condition, soft-tissue characteristics, predisposition to edema, and the status of the muscular component. Treatment response is proposed to be evaluated across several domains: changes in skin quality, the degree of lifting and changes in soft-tissue shape, stability of the outcome in patients predisposed to edema, and changes in features associated with muscle tone. A matrix linking baseline characteristics to the anticipated response was developed, five typical response profiles were defined, and a framework for subsequent clinical validation of the model was proposed. The findings support a shift toward outcome prediction that integrates the patient's baseline phenotype with the characteristics of the intervention applied.

**Keywords:** facial rejuvenation, predictors of effectiveness, noninvasive methods, skin condition, facial soft tissues, edema, muscle tone, radiofrequency treatment, microfocused ultrasound, multimodal correction

## 1. Introduction

Age-related facial changes result from interrelated alterations in the skin, subcutaneous tissues, fat compartments, connective tissue structures, and muscles. Consequently, clinically similar signs of aging may have different anatomical origins. For example, changes in the lower third of the face may be associated with reduced skin elasticity in one patient, displacement of soft tissues in another, and tissue changes accompanied by edema or differences in muscle status in a third. Current approaches to facial rejuvenation are therefore increasingly shifting toward preliminary assessment of individual anatomical layers and selection of interventions according to the predominant changes (Rohrich et al., 2026; Chennupati et al., 2026).

Noninvasive facial rejuvenation technologies also differ in their target tissues and mechanisms of action.

Radiofrequency modalities, for example, are used to deliver controlled thermal energy to the dermis and underlying tissues. Microfocused ultrasound creates treatment zones at predetermined depths and is used primarily to address reduced tissue firmness and varying degrees of tissue ptosis. Neuromuscular stimulation technologies represent a distinct therapeutic approach. In clinical practice, these modalities may be used sequentially, allowing multiple components of age-related facial changes to be targeted (Sieber, Kenkel, 2018; Austin et al., 2022; Chilukuri, 2023).

However, the use of a single technology according to a standardized protocol does not guarantee a comparable magnitude of response across patients. Studies of microfocused ultrasound demonstrate that outcomes depend on the degree of baseline tissue laxity and certain anthropometric characteristics. In one clinical study, less pronounced changes were observed in patients with a body mass index above 30 kg/m², whereas better outcomes were reported in individuals with lower soft-tissue volume (Oni et al., 2014). Systematic reviews likewise confirm variability in outcomes associated with patients' baseline characteristics, treatment parameters, and the assessment methods used (Contini et al., 2023; Amiri et al., 2025).

In light of the above, the research question needs to be reframed. In the context of multimodal noninvasive facial rejuvenation, an important consideration is which baseline patient characteristics may predict the nature of the subsequent treatment response. This requires distinguishing overall aesthetic effectiveness from individual components of the outcome. Improvement in skin texture may not be accompanied by a noticeable change in soft-tissue position, while a pronounced lifting effect may occur despite persistent edema. Changes in muscle status may also affect the shape of individual facial regions independently of dermal remodeling processes. The aim of this study is to systematize potential predictors of the effectiveness of multimodal noninvasive facial rejuvenation and to develop a conceptual multifactorial model of predicted response that takes into account skin condition, soft-tissue characteristics, predisposition to edema, and muscle tone.

## 2. Materials and Methods

The study was based on peer-reviewed scientific publications addressing age-related facial changes, noninvasive correction methods, assessment of skin laxity, microfocused ultrasound, radiofrequency technologies, neuromuscular stimulation, midfacial and periorbital edema, and objective assessment of aesthetic outcomes.

In selecting the materials, priority was given to systematic reviews, prospective clinical studies, controlled studies, and publications in which patients' baseline characteristics could be compared with the magnitude of subsequent changes.

The analysis was conducted sequentially:

1. the main components of the response to noninvasive rejuvenation were identified;
2. baseline characteristics potentially affecting the magnitude of this response were systematized;
3. the outcome component with which each characteristic might be primarily associated was assessed;
4. a conceptual model was developed, and a framework for its subsequent clinical validation was established.

For the purposes of this study, the response to multimodal noninvasive rejuvenation is defined as the set of changes observed following treatment relative to the patient's baseline condition. This response comprises four components:

- changes in skin quality, including texture, elasticity, and the severity of superficial signs of aging;

- changes in soft-tissue condition, including the degree of lifting, laxity, and the visual characteristics of individual facial regions;
- changes in or persistence of edema that may affect the visual assessment of facial shape;
- changes in features associated with muscle status and the dynamic component of facial appearance.

Global aesthetic assessment and patient satisfaction are considered overall outcome measures derived from the components described above. This approach is consistent with current methods for evaluating aesthetic procedures, in which photographic scales, instrumental measurements, and subjective patient assessments capture different aspects of the outcome (Zhao et al., 2025).

## 3. Results and Discussion

The analysis of the scientific literature identified four groups of baseline characteristics that may need to be considered when predicting the response to noninvasive facial rejuvenation: skin condition, soft-tissue characteristics, predisposition to edema, and the status of the muscular component. Each group is considered separately below.

The first group comprises baseline skin characteristics; skin condition accounts for a substantial proportion of the visible signs of aging and also influences the selection of a noninvasive technology. Parameters of interest during the initial assessment include the severity of photoaging, elasticity, texture, skin barrier status, phototype, and the depth of the predominant age-related changes. Current recommendations for nonsurgical rejuvenation generally include assessment of several of these parameters before selecting a procedure (Chennupati et al., 2026).

Of particular importance is distinguishing the severity of superficial signs from structural changes in the soft tissues. A patient with pronounced photoaging and relatively preserved tissue support may exhibit a different response pattern from a patient whose predominant manifestation is soft-tissue displacement despite comparatively well-preserved skin condition.

Accordingly, skin elasticity can be assessed instrumentally using devices based on controlled mechanical stimulation. However, such measurements require standardization of the measurement site, patient positioning, and testing conditions. Therefore, skin condition should be assessed using multiple parameters within the predictive model rather than relying on a single instrumental measure.

The second group of predictors is related to facial soft tissues. This group is most closely associated with predicting the lifting effect. Studies of microfocused ultrasound have shown the most predictable changes in patients with moderate tissue laxity. In the presence of pronounced structural changes, the potential of noninvasive correction is inherently limited (Oni et al., 2014; Contini et al., 2023). Characteristics of particular interest include the degree of tissue ptosis, volume distribution, soft-tissue prominence in the lower third of the face and the submental region. Body mass index may be used as an additional characteristic to complement the overall assessment.

The third group is related to predisposition to edema. This factor is rarely considered an independent predictor of rejuvenation outcomes, although its clinical significance is substantial. Midfacial edema, malar mounds, and festoons have distinct underlying characteristics and should be assessed separately (Newberry et al., 2020; Jeon et al., 2021; Quah, Ezra, 2026).

The presence of an edematous component may alter the visual perception of the outcome; a reduction in tissue laxity in the presence of persistent, pronounced edema may not be accompanied by the expected improvement in midfacial contour. Conversely, fluctuations in the severity of edema may create the impression of a change in outcome in the absence of substantial structural changes. Predisposition to edema is therefore proposed as a modifier of the visual response. This designation appears more appropriate than classifying edema as a universal negative predictor, since the significance of this feature depends on the treatment area, baseline tissue condition, and the method selected.

The fourth group concerns muscle status; facial muscles contribute, at a minimum, to the development of dynamic signs of aging and may influence the shape of individual facial regions. For example, studies of neuromuscular electrical stimulation have demonstrated the potential to alter the thickness of individual muscles and associated visual facial characteristics (Kavanagh et al., 2012). More recent studies using objective imaging methods have also confirmed an association between changes in muscle morphology and external facial parameters (Okuda et al., 2026).

The available evidence supports the inclusion of the muscular component in the predictive model; however, there is currently insufficient evidence to establish universal reference values for "optimal" muscle tone. The role of this component should be evaluated primarily when technologies that directly target the neuromuscular system are used. The relationship between the identified characteristics and the anticipated response to noninvasive facial rejuvenation is presented in Table 1.

**Table 1.** Matrix of potential predictors of the effectiveness of multimodal noninvasive facial rejuvenation

| **Predictor group** | **Key baseline characteristics** | **Primary associated response component** | **Interpretation** |
|---|---|---|---|
| Skin condition | photoaging, elasticity, texture, skin barrier status, phototype | skin quality | significance depends on the technology used and the depth of treatment |
| Soft tissues | degree of laxity, volume distribution, condition of the lower third of the face, submental region | lifting and changes in facial shape | clinical evidence supports considering the baseline severity of changes a significant factor |
| Predisposition to edema | malar and periorbital edema, festoons, changes in edema over time | visual stability of the outcome | may accentuate or mask changes in tissue shape |
| Muscular component | muscle tone, dynamic patterns, thickness of individual muscles | changes in muscle-associated features | particularly relevant to neuromuscular stimulation technologies |
| Additional factors | age, BMI, previous procedures, smoking, treatment parameters | multiple response components | considered covariates in subsequent validation of the model |

The proposed systematization indicates that no single baseline characteristic should be regarded as a universal predictor; rather, consideration should be given to the specific component of age-related changes targeted by a given intervention. This principle is proposed as the basis for the conceptual predictive model (see Fig. 1):

As can be seen, the effect of a procedure is not determined solely by the use of a particular technology. The patient's baseline condition lies between the selected intervention and the final outcome and may modify the nature of the response. On this basis, we propose a multifactorial model (see Fig. 2).

An important feature of the model is that it does not rely on a single composite measure of effectiveness prior to clinical validation. Instead, the prediction should characterize the anticipated response across individual outcome domains. For example, one patient may be predicted to experience a pronounced improvement in skin quality with only limited change in the shape of the lower third of the face, whereas in another patient,

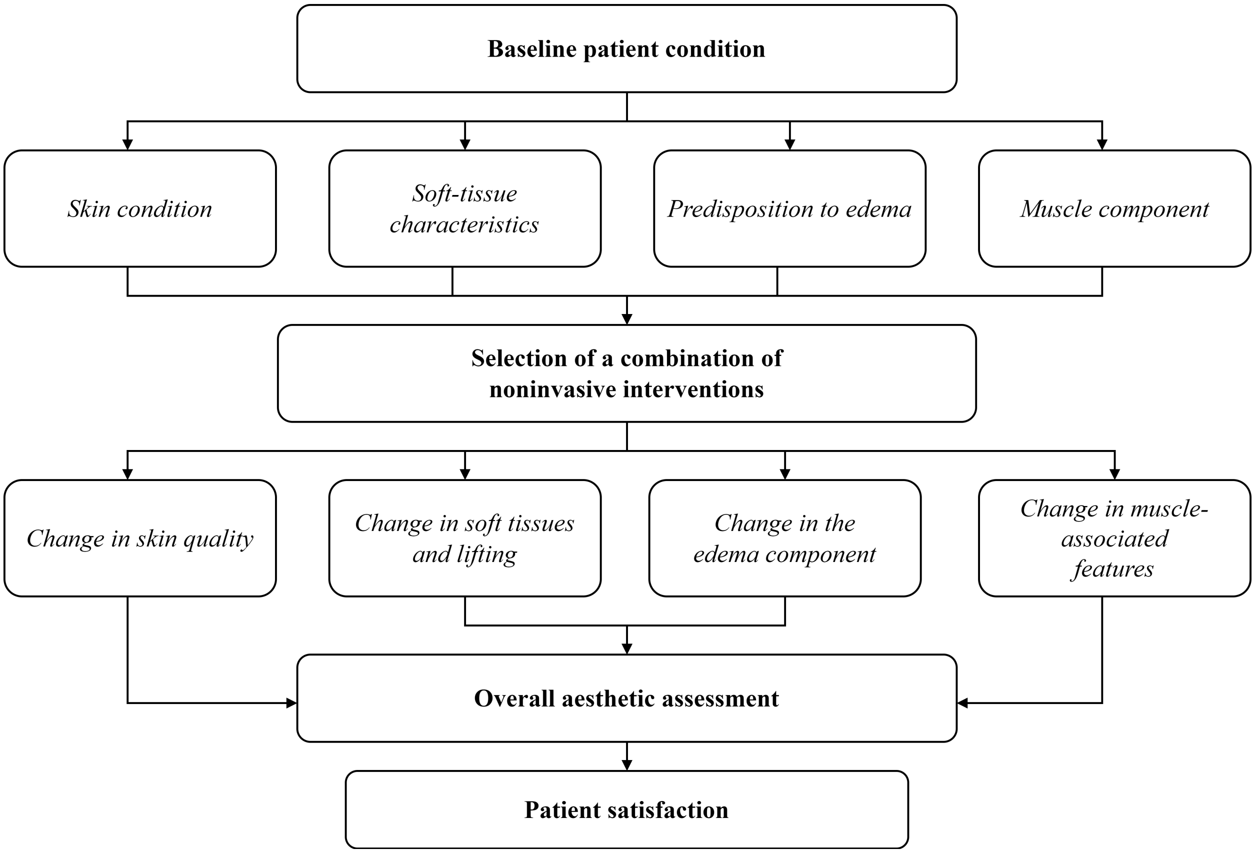


**Figure 1.** Formation of the response to multimodal noninvasive facial rejuvenation

the most likely outcome may be a reduction in tissue laxity with only minor changes in superficial skin characteristics.

Based on the integration of the four groups of potential predictors, five typical profiles of predicted response are proposed.

1. predominantly skin-related. Most visible age-related changes in this profile are attributable to skin condition, including reduced elasticity, changes in texture, fine wrinkles, and signs of photoaging. Structural displacement of the soft tissues and the edematous component are limited, and the expected response to multimodal treatment is focused primarily on improvements in skin characteristics;

2. predominantly soft-tissue-related. The dominant manifestations in this profile are moderate laxity and changes in soft-tissue position. Accordingly, the relationship between the baseline severity of ptosis and the capabilities of the selected technology becomes particularly important. Studies of microfocused ultrasound indicate more predictable outcomes in patients with moderate changes than in those with pronounced tissue ptosis (Oni et al., 2014; Yalici-Armagan, Elcin, 2020);

3. pronounced edematous component. Midfacial or periorbital edema substantially affects the perception of facial shape. Structural changes in the tissues following treatment may be visually masked by persistent edema. For patients with this profile, prediction should account for potential changes in the fluid component separately from the lifting outcome itself. Current publications on infraorbital rejuvenation also support distinguishing among tissue laxity, malar edema, and malar bags before selecting an intervention (Heitzmann et al., 2026);

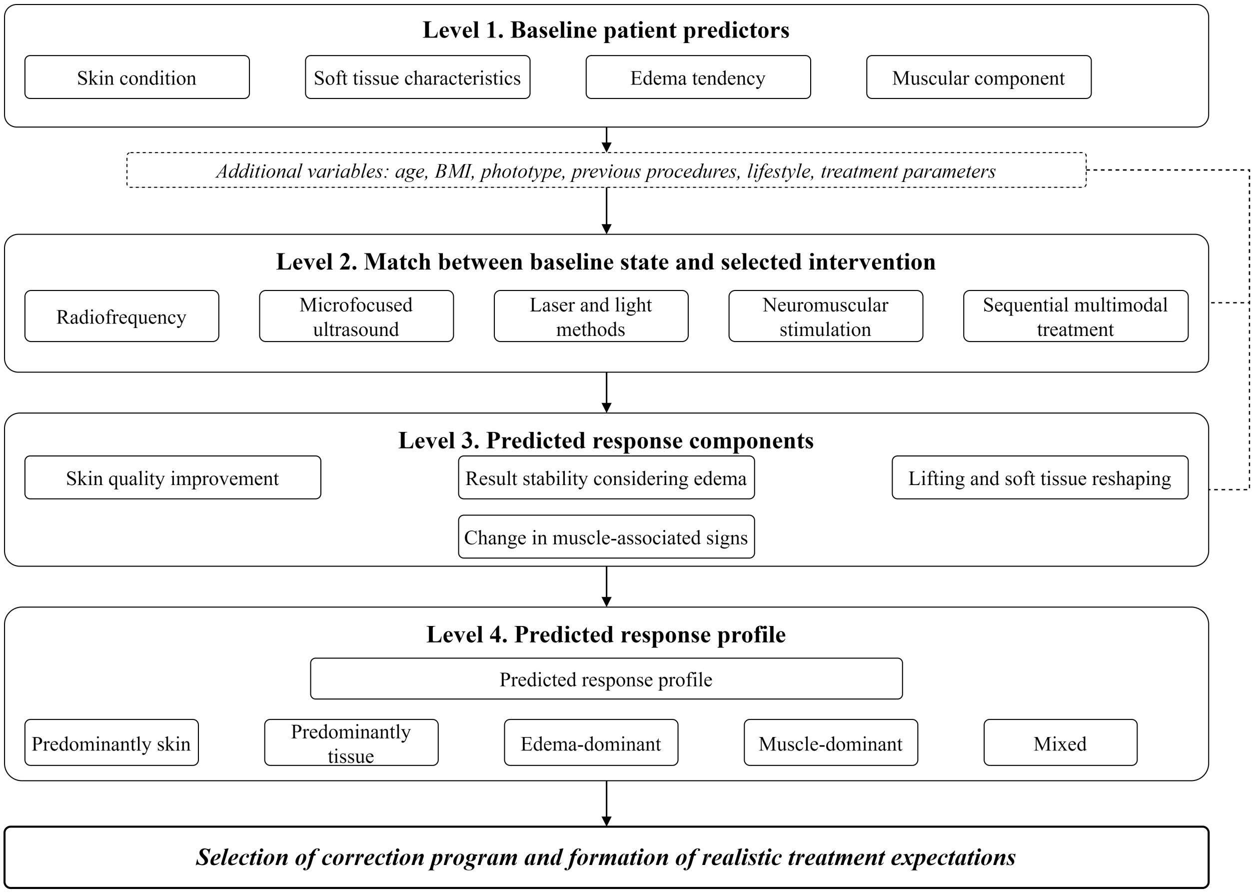


**Figure 2.** Conceptual model for predicting the effectiveness of multimodal noninvasive facial rejuvenation

4. substantial muscular component. The severity of visible changes is associated with the condition of the facial muscles and their functional characteristics. In this profile, neuromuscular stimulation technologies may potentially contribute more to the resulting change in facial shape than in a predominantly skin-related pattern of aging;

5. mixed profile, in which several components are of comparable importance. This profile appears particularly characteristic of a multimodal approach, since targeting a single tissue layer may account for only part of the expected outcome.

An important limitation should be noted: the proposed profiles are not independent diagnoses and do not establish indications for specific procedures. Their purpose is to provide a research framework for subsequent evaluation of the relationship between the baseline phenotype and the nature of the response.

The proposed system therefore also helps clarify the meaning of "effectiveness" itself, which should be assessed in relation to the intended treatment objective. If the aim of the intervention is to improve skin quality, the absence of a pronounced lifting effect cannot be interpreted as an unsatisfactory outcome. Similarly, a favorable lifting response does not indicate improvement in photodamage or other superficial skin characteristics. Accordingly, the target outcome components should be defined before the procedure and subsequently assessed independently.

A prospective study design is proposed for subsequent validation of the conceptual model. The proposed sequence is presented in Fig. 3.

Thus, at the clinical validation stage, standardization of measurements is of particular importance. For example,

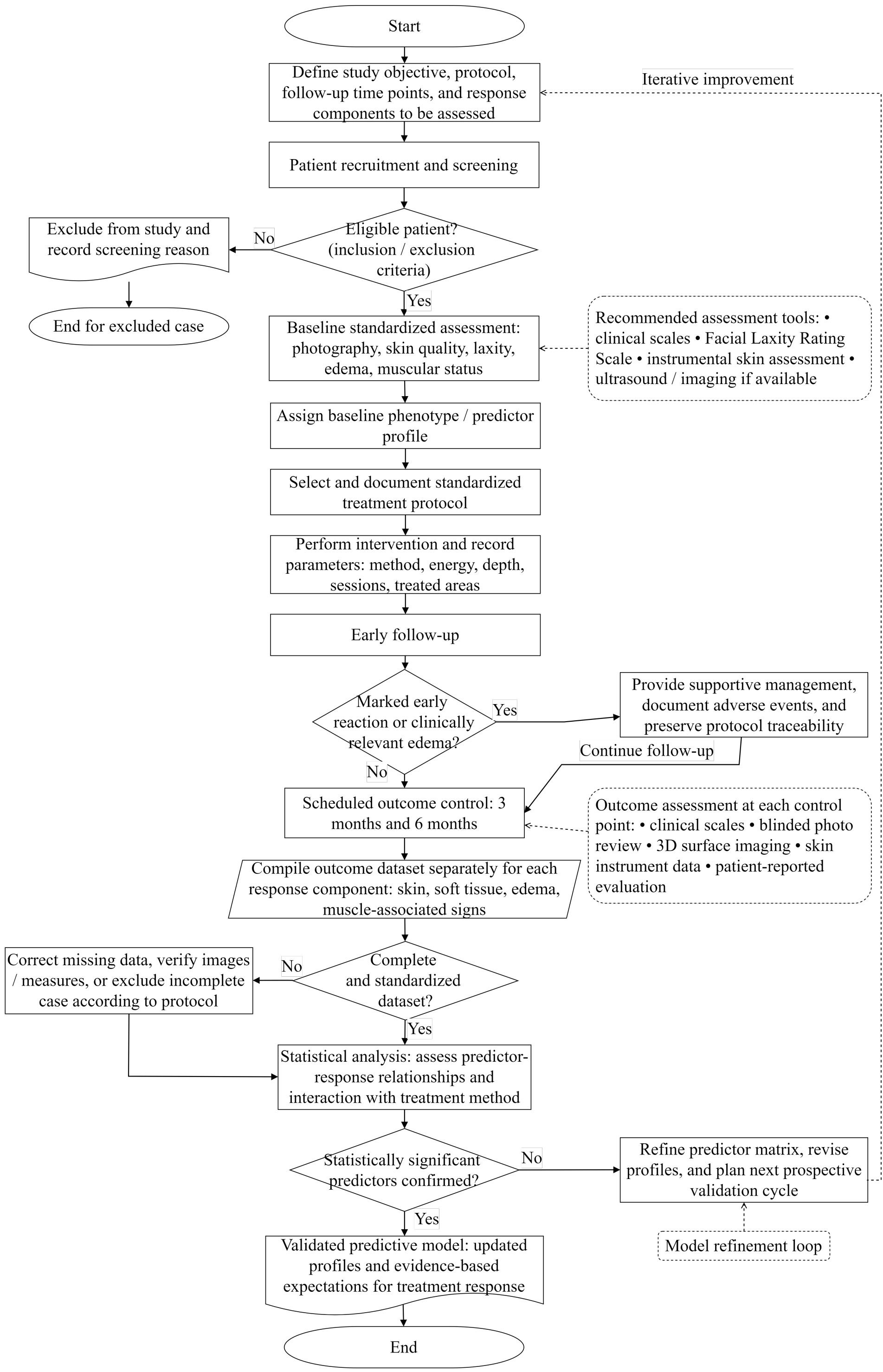


**Figure 3.** Clinical validation methodology for the conceptual response-prediction model

validated clinical scales, such as the Facial Laxity Rating Scale, may be used to assess tissue laxity (Leal Silva, 2016). Three-dimensional imaging enables objective assessment of changes in facial surface characteristics and specific parameters of facial shape while reducing reliance on subjective evaluation of photographs (Nguyen et al., 2022; Sun et al., 2026). Where appropriate equipment is available, skin assessment may be supplemented by biophysical measurements. Assessment of facial muscle status should employ a reproducible ultrasound-based or other instrumental method; edema should be recorded separately, as changes in edema may independently affect the visual outcome.

In the subsequent statistical analysis, the association between baseline characteristics and changes in each outcome component should be assessed. In addition to the main effects, interactions between predictors and the methods applied should be examined. For example, the degree of tissue laxity may be an important factor in microfocused ultrasound treatment but may play a substantially smaller role in a procedure primarily targeting superficial skin characteristics. This approach avoids artificially combining heterogeneous procedures into a single outcome scale.

However, the conceptual model has several limitations. Most existing studies focus on evaluating the effectiveness of specific procedures rather than identifying baseline predictors; moreover, they use different devices, protocols, energy levels, treatment areas, follow-up periods, and assessment methods. Systematic reviews of radiofrequency methods and microfocused ultrasound confirm the clinical effectiveness of these approaches while also demonstrating substantial heterogeneity across studies (Austin et al., 2022; Vassão et al., 2022; Amiri et al., 2025). At present, the evidence base for assessing skin condition and the degree of tissue laxity is broader than that for predisposition to edema and the muscular component. Therefore, the latter two groups should be regarded as well-founded potential predictors requiring targeted investigation.

The scientific significance and novelty of the proposed approach lie in its potential to predict individual response patterns. The unit of analysis is the relationship between the patient's baseline condition and the treatment parameters. Consequently, the assessment of predictors of effectiveness may enable the identification, in advance, of the outcome components in which the most pronounced changes are expected, the delineation of likely limitations, and the development of a more evidence-based plan for multimodal noninvasive correction.

## 4. Conclusions

Thus, the study systematized potential predictors of the effectiveness of multimodal noninvasive facial rejuvenation and integrated them into a conceptual model for predicting treatment response.

Four groups of characteristics were identified as components of the patient's baseline condition: skin condition, soft-tissue characteristics, predisposition to edema, and the status of the muscular component. Their associations with individual components of the response are proposed to be evaluated separately: skin quality, soft-tissue changes, changes in the edematous component, and changes in features associated with muscle status.

Based on the identified characteristics, five typical profiles of predicted response were defined: predominantly skin-related, predominantly soft-tissue-related, a profile with a pronounced edematous component, a profile with a substantial muscular component, and a mixed profile. The proposed typology is intended for subsequent clinical validation and, importantly, is not currently intended to serve as a system for determining indications for specific procedures.

The proposed model accounts for the dependence of treatment outcomes on the alignment between the patient's baseline characteristics and the target of the selected technology. This principle is particularly relevant to multimodal rejuvenation, as different methods target different tissue layers.

A framework for subsequent clinical validation was developed, including standardized assessment of baseline status, implementation of a standardized treatment protocol, follow-up at predefined time points, separate evaluation of outcome components, and statistical testing of potential predictors.

A prospective clinical study is planned to identify statistically significant baseline characteristics, assess the effects of their combinations, and develop a validated model for individualized prediction of the effectiveness of multimodal noninvasive facial rejuvenation, with the findings to be reported in future publications by the author.

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