Validated 5-Point Photonumeric Skin Quality Assessment Scale for Asian Populations: Digital and Live Reliability Analysis

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Abstract

Background: Skin quality is a multidimensional aesthetic construct encompassing multiple parameters such as skin surface evenness, tone evenness, firmness, and glow. Despite its clinical relevance, standardized tools for objectively grading skin quality in Asian populations remain limited. To address this gap, a 5-point photonumeric Skin Quality Assessment Scale was developed.

Objective: To develop and validate a standardized 5-grade photonumeric scale for assessing overall skin quality in Asian subjects through digital and live evaluations.

Methods: A total of 100 subjects (84 females, 16 males) were selected from a standardized photo database, for which all images were acquired under standardized studio conditions. Asian and international aesthetic experts performed two digital rating sessions, each evaluating all 100 subjects according to a 5-point ordinal scale (grades 0-4). After a two-week period, raters repeated all assessments in a new randomized sequence to measure intra-rater reliability. For clinical validation, 95 subjects (69 females, 26 males) underwent live, in-person evaluation by a panel of Asian and international experts following the same two-session design. Inter-rater and intra-rater reliability were quantified using Intraclass Correlation Coefficients (ICC 2,1) and weighted Cohen's kappa (Fleiss–Cohen quadratic weights), respectively.

Results: Digital validation demonstrated substantial inter-rater reliability across both sessions (ICC 2,1: 0.77; weighted kappa: 0.77), while intra-rater reliability was excellent (ICC 2,1: 0.84; weighted kappa: 0.83). Live validation confirmed the scale's robustness, showing substantial inter-rater agreement (ICC 2,1: 0.77; weighted kappa: 0.77) and excellent intra-rater reproducibility (ICC 2,1: 0.88; weighted kappa: 0.88).

Conclusion: The 5-point photonumeric Skin Quality Assessment Scale shows substantial inter-rater reliability and excellent intra-rater consistency in both digital and live evaluations. Purpose-built for Asian skin characteristics, the scale provides a scientifically validated, standardized tool suitable for clinical studies, treatment monitoring, and objective aesthetic assessment.

Introduction

Skin quality is a central component of facial attractiveness and a key determinant of perceived health, vitality, and youthfulness.[1,2] In aesthetic medicine, the term "skin quality" encompasses multiple interrelated skin attributes that in sum shape the overall appearance of the skin. These include skin surface evenness, skin tone evenness, skin firmness, and skin glow, four domains that reflect the integrity and status of the epidermis and dermis, chromophore distribution, extracellular matrix structure, hydration, and light-scattering properties of the skin.[3,4] Skin surface evenness describes the epidermal relief and is majorly influenced by the uniformity of micro- and macro-topographical patterns, such as pores, superficial lines, or coarse rhytides, which are the result of epidermal turnover and dermal matrix composition.[5] Skin tone evenness reflects the homogeneity of pigmentation distribution, with dyschromia, mottling, and irregularities resulting from inflammation, vascular changes, or cumulative ultraviolet exposure with melanin.[6,7] Skin firmness is a component of skin quality which focuses primarily on the mechanical resilience including parameters such as elasticity, recoil, and resistance to deformation, all driven largely by quantity and quality of collagen and elastin.[8,9] Finally, skin glow represents the skin's optical quality and perception, shaped by hydration, smoothness, light reflectance, and microcirculation, contributing to what is commonly perceived as "radiance".[10,11] Collectively, these parameters define a multidimensional framework for the assessment of skin quality in clinical practice and research. However, despite its growing relevance in aesthetic dermatology, validated and standardized tools for the objective assessment of skin quality, particularly in Asian populations, remain scarce. Ethnic differences become particularly relevant considering that Asian skin often exhibits distinct anatomical and biological characteristics, including a higher melanin content, a thicker and more compact dermis, and distinctive aging patterns.[12,13] Such differences underscore the need for population-specific photonumeric scales that can accurately and reproducibly capture the degree of skin quality changes. Photonumeric assessment scales have become essential tools for clinical trials, treatment evaluation, and communication between clinicians and patients.[14–18] Their value lies in providing standardized visual anchors and consistent grading criteria, reducing subjectivity and thereby improving reproducibility. High-quality, validated scales are particularly important when evaluating subtle features such as skin texture or radiance, which are prone to variability across raters and imaging conditions.[19]

To address this unmet clinical need, a 5-grade photonumeric Skin Quality Assessment Scale was developed using carefully curated reference images and validated according to established scientific protocols.[18,20,21] Validation included digital assessments of standardized

photographs as well as live clinical evaluations, enabling quantification of both inter-rater and intra-rater reliability. The present study reports the development and validation of a 5-point Skin Quality Assessment Scale, specifically designed for Asian skin, aiming to establish a robust, reproducible, and clinically practical tool.

Material and Methods

Photographic database & participants

All participants provided written informed consent and agreed to the use of their photographs for validation purposes prior to their inclusion into the study. The participants met predefined inclusion and exclusion criteria. (*Table 1)* A comprehensive photo database was established using standardized 2D photographs in a professional studio environment. To ensure consistency across images, all participants were photographed by a trained photographer under controlled conditions. A Nikon Z7 II camera (4,912×7,360 px) was used with fixed settings (portrait view, f/22, 1/200 s, 200 ASA, 200 mm focal length). Subjects were photographed in a seated position to minimize movement, with standardized distances maintained between the subject, lights (140 cm), and camera (180 cm). A middle-hued blue background was used to facilitate post-production. Lighting was carefully controlled using a symmetrical two-soft light setup to avoid shadows that could influence assessment.

After establishing the standardized photographic database, a medical team comprising dermatologists and plastic surgeons, reviewed all images and selected 100 subjects representing both sexes, a broad age range, and the full spectrum of skin quality severities. A panel of four international aesthetic experts then independently graded overall skin quality for all selected subjects using a digital platform and the predefined 5-point ordinal scale (grades 0–4). Representative anchor images for grade 0 and grade 4 were provided to ensure consistent grading. Mean expert ratings were used to rank subjects and assign each to its respective severity grade. To construct the photonumeric scale, the medical team selected a representative image of mid-grade severity (i.e., grade 2 or 3) as the base for generating morphed reference images. Additional images showing varying degrees of fine lines, roughness, dullness, and dryness were overlaid onto the base image under close supervision to create visually accurate representations for each grade. A photoguide was then compiled by selecting four real, expert-rated subject images per grade to illustrate natural variability within each severity level. Standardized textual descriptors were finalized to accompany these visual anchors.

The finalized 5-point Skin Quality Assessment Scale therefore comprises: (i) standardized descriptors, (ii) morphed reference images, and (iii) multiple real subject examples per grade.

Together, these components form a concise, clinically applicable tool tailored to typical skin quality presentations in Asian populations.

Skin Quality Assessment Scale Development

The Skin Quality Scale was constructed as a 5-point photonumeric ordinal scale (grades 0-4), with each grade defined by standardized descriptors (fine lines, dullness, dryness, roughness) and anchored by carefully selected reference images. (*Figure 1* and *Table 2)* The scale was developed to reflect key domains of skin quality, including surface evenness (fine lines, roughness), skin tone evenness, skin firmness, and skin tone dullness/loss of radiance, and was designed specifically for use in Asian populations.

Digital and Live Validation of the Skin Quality Assessment Scale

Digital validation was conducted in two rating sessions by Asian and international aesthetic experts (n=13). Prior to commencing the evaluations, all raters underwent an interactive online training session that included detailed explanations of the scale descriptors, instructions on grade discrimination, and practice using example images. A web-based platform was used to ensure pseudonymous subject management, randomized image presentation, and equal distribution across severity grades. After the first rating session, a two-week interval as a "washout period" was implemented. Experts then repeated the evaluation using a new randomization order of the previously rated images to allow for the assessment of intra-rater reliability. Live validation was performed in person with 95 subjects being evaluated in a clinical setting by trained Asian and international aesthetic experts (n=7) following protocols parallel to the digital validation. Raters underwent the same training procedures as in the digital phase, with emphasis on uniform application of the scale. Each subject was assessed in two separate live sessions, enabling the calculation of both inter-rater and intra-rater reliability under real-world clinical conditions.

Statistical Analysis

Reliability was quantified using the Intraclass Correlation Coefficient (ICC 2,1) based on the Shrout and Fleiss two-way random-effects model, as well as weighted Cohen's kappa calculated with Fleiss-Cohen quadratic weights.[22,23] Inter-rater reliability was assessed separately for each rating session, while intra-rater reliability was derived from both sessions

for each evaluator and summarized using mean values, ranges, and confidence intervals. ICC values were interpreted according to established benchmarks, ranging from slight (0.00-0.20), fair agreement (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80) to almost perfect agreement (≥0.81).[24] Weighted kappa values were additionally reported because, with ordinal scales and large sample sizes, quadratic-weighted kappa is statistically approximately equivalent to ICC 2,1, providing a complementary measure of agreement. All procedures underwent quality control to ensure robustness of statistical outputs, and all statistical analyses were performed in Python 3.8 using NumPy (v1.23.4), pandas (v1.5.2), scikit-learn (v1.0.2), and pingouin (v0.5.2).

Results

Study setup and subject demographics

The digital validation was based on a photographic database comprising 160 subjects (123 females and 37 males) of Asian ethnical background. For the Skin Quality Assessment Scale specifically, 100 subjects were selected from this pool, ensuring balanced distribution across the full range of severity grades. In the subsequent live validation, 95 subjects (69 females, 26 males) participated for the in-person assessments. The live-validation cohort had a mean age of 39.1±14.2 years.

Digital Validation

In the digital validation, the Skin Quality Asessment Scale showed consistently strong agreement across both rating sessions. Inter-rater reliability demonstrated substantial concordance among evaluators, with an ICC of 0.77 (95% CI: 0.72-0.82) in the first session and 0.77 (95% CI: 0.71-0.82) in the second session. Weighted Cohen's kappa held identical outcomes, with values of 0.77 (95% CI: 0.75-0.78) and 0.77 (95% CI: 0.76-0.78) for the first and second session, respectively. Intra-rater reliability for the Skin Quality Assessment Scale was almost perfect with mean ICC across evaluators being 0.84 [range: 0.78-0.91] and weighted kappa showed a mean of 0.83 [range: 0.78-0.91].

Live Validation

The inter-rater agreement during in-person evaluations remained substantial, with ICC values of 0.77 (95% CI: 0.69-0.84) and 0.77 (95% CI: 0.68-0.84) in the first and second session, respectively. Weighted kappa values were equally consistent, with both sessions yielding values of 0.77 (95% CI: 0.75-0.79 and 95% CI: 0.75-0.80, respectively). Intra-rater reliability in the live phase was again almost perfect and showed a mean ICC of 0.88 [range: 0.83-0.90] and weighted kappa results showed a mean of 0.88 [range: 0.83-0.90].

Discussion

This study presents the development and validation of a 5-point photonumeric scale specifically designed for the objective assessment of facial skin quality in Asian populations. Skin quality is increasingly recognized as a multidimensional aesthetic construct and a central determinant of perceived attractiveness.[1,2] Yet, despite its clinical importance, standardized and validated tools capable of reliably capturing these nuanced features remain scarce, particularly for Asian individuals whose skin displays distinct characteristics compared to populations of Caucasian ethnic background.[19] The creation of a validated and clinically applicable scale tailored to the needs of this population therefore addresses a clear gap.

Asian skin differs from Western skin in several clinically relevant aspects, including baseline melanin density, differing patterns of photoaging, unique dermal thickness distribution, and characteristic manifestations of texture and tone irregularities.[25–27] Such population-specific variations are capable of influencing the perception of fine lines, dullness, dryness, and roughness of the skin. Accordingly, the use of photonumeric tools not tailored to specific populations may lead to misclassification or reduced rating sensitivity. This holds special relevance in a context when assessor and subject differ in ethnic background.[28] By anchoring the scale in phenotype-appropriate visual references and descriptors, the present work ensures that the evaluation of skin quality aligns closely with the typical presentation and aging patterns of Asian skin.

A strength of the study presented herein lies in the high degree of standardization in the photographic methodology used for digital validation. The controlled imaging environment, including fixed camera parameters, consistent lighting, and uniform background selection, reduces variation which might potentially undermine reproducible aesthetic assessment.[29] This methodological rigor, paired with appropriately selected grade descriptors, is reflected in the strong reliability outcomes observed in the digital phase, with inter-rater agreements (ICC) of 0.77 and weighted kappa values of 0.77 across both sessions.[24] Such reproducibility alludes that raters were indeed evaluating genuine differences in the skin quality of subjects rather than artifacts in the image acquisition.

The reliability outcomes demonstrated in this study further reinforce the robustness of the scale. Intra-rater reliability in the digital phase reached an excellent mean ICC of 0.84, with weighted kappa at 0.83, indicating that evaluators were highly consistent in their assessments over time. Under real-world conditions, the live validation arm of this study produced comparable results with inter-rater reliability again reaching an ICC of 0.77, and intra-rater reliability improving further to 0.88. These values effectively demonstrate that the Skin Quality

Assessment Scale performs reliably not only in standardized photographic evaluations (i.e., digital validation) but also during direct clinical examination (i.e., live validation).

Cross-cultural expert involvement adds an additional layer of robustness to the validation and should hence be considered a strength of the study. Including both Asian and international aesthetic specialists ensured that the scale could be interpreted consistently across different clinical backgrounds. The high agreement among raters from varied cultural and professional environments reinforces the universal interpretability of the scale's grading system while maintaining population specificity.

Methodologically, the study benefits from a rigorous validation design. The two-session structure for both digital and live assessments, combined with a two-week washout period and randomized image ordering, minimized memory bias and allowed robust quantification of both inter- and intra-rater variability. The strong alignment between the digital and live results underscores the scale's versatility and confirms its suitability for use across different settings, including controlled research environments to busy clinical practices.

Despite its strengths, this study, however, is not free of limitations. Although the inter- and intra-rater reliability values were high, the scale and the nature of aesthetic assessments remain inherently subjective, dependent on human interpretation. Even with standardized training, subtle perceptual differences between individuals cannot be entirely eliminated. Further, the scale was validated exclusively in Asian populations. While this demographic focus aligns with the scale's originally intended purpose, it limits generalizability and external validity to other ethnic groups with differing skin physiology and aging patterns.

In summary, the 5-point photonumeric Skin Quality Assessment Scale provides a validated, reliable, and clinically practical tool for evaluating the multidimensional construct of skin quality in Asian subjects. Its strong performance, demonstrated by substantial inter-rater reliability and excellent intra-rater reproducibility across both digital and live evaluations, provides strong evidence for its application in clinical practice, research settings, and treatment monitoring. The scale fills an hitherto unmet gap in standardized aesthetic assessment and offers a foundation for future advancements in objective, population-specific evaluation of skin quality.

Conclusion

The present study developed and validated a 5-point photonumeric Skin Quality Assessment Scale purpose-built for Asian populations. The scale demonstrated substantial inter-rater agreement (ICC 0.77) and excellent intra-rater reproducibility (up to ICC 0.88) across both digital and live evaluations, confirming its reliability in controlled photographic settings as well as real-world clinical use. By providing standardized visual anchors tailored to Asian skin characteristics, the scale addresses a critical need for objective, reproducible assessment of skin quality in aesthetic practice and research for this ethnic population.

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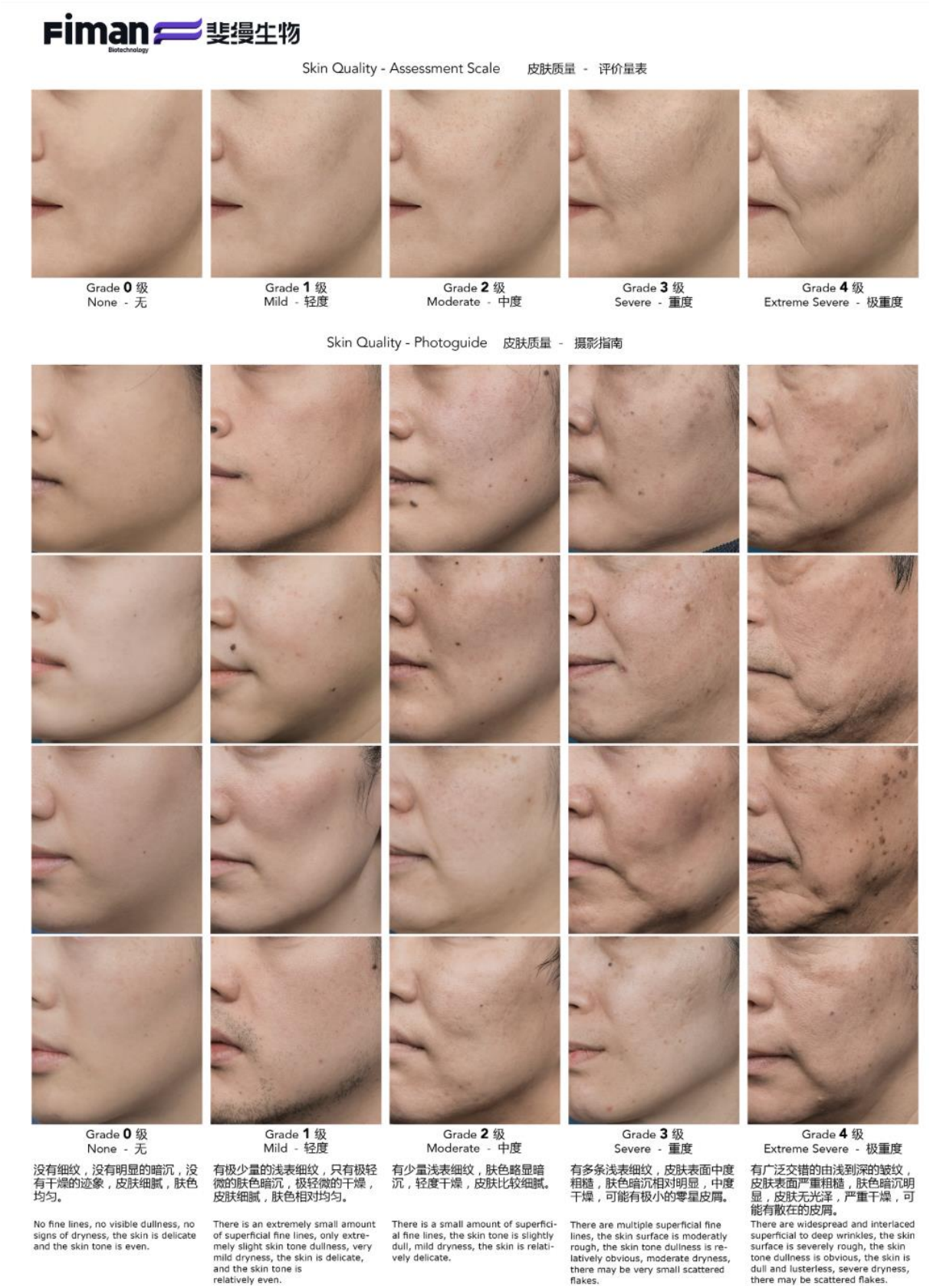
Figure legends

Figure 1: Skin Quality Assessment Scale



Tables

Table 1: Inclusion and exclusion criteria for participants to be photographed and included in the database used for the development of the Skin Quality Assessment Scale.

Inclusion criteria	**Exclusion criteria**
1) Asian male or female, 18 years of age or older	1) Permanent makeup or tattoos in assessment areas
2) Healthy facial skin free from diseases that could affect evaluation	2) Previous major reconstructive facial surgery
3) Willingness to refrain from aesthetic or surgical procedures between photo shoot and live evaluation	3) Infectious, inflammatory, or proliferative lesions in treatment areas
4) Written signed and dated informed consent	4) Subjects whose participation in clinical trials is prohibited by national regulations
5) Capable of understanding study information and willing to participate	

Table 2: Definition and grading of the Skin Quality Assessment Scale ranging from grade 0-4.

Grades	**Description**
Grade 0	*"No fine lines, no visible dullness, no signs of dryness, the skin is delicate and the skin tone is even."*
Grade 1	*"There is an extremely small amount of superficial fine lines, only extremely slight skin tone dullness, very mild dryness, the skin is delicate, and the skin tone is relatively even."*
Grade 2	*"There is a small amount of superficial fine lines, the skin tone is slightly dull, mild dryness, the skin is relatively delicate."*
Grade 3	*"There are multiple superficial fine lines, the skin surface is moderately rough, the skin tone dullness is relatively obvious, moderate dryness, there may be very small scattered flakes."*
Grade 4	*"There are widespread and interlaced superficial to deep wrinkles, the skin surface is severely rough, the skin tone dullness is obvious, the skin is dull and lusterless, severe dryness, there may be scattered flakes."*