Translating Cosmetic Results into Rejuvenation Years : Introducing the Modified Skin Youthfulness Index (SYIm)

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Topic
UV protection, Suncare, Consumer tests & Sensory Analysis + 1 plus

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Introduction – Skin : Bridging Chronological Age and Behavioral Age

Skin aging is a remarkably complex and multifactorial biological process. It has long captivated the scientific community, which is largely due to its partially elusive origins. The onset of aging is generally considered to be around 25 years old [1]. At this point, the skin barrier starts to lose integrity, leading increased dryness and heightened sensibility to external aggressors such as ultraviolet radiation and oxidative stress, often aggravated by pollution. Concurrently, dermal collagen synthesis declines, directly affecting the skin's biomechanical properties, including firmness and elasticity. The internal changes are accompanied by visible alterations in skin texture and pigmentation, with symptoms such as roughness, wrinkles and pigmentary disorders, including age spots (senile lentigines), becoming increasingly evident [2].

Chronological aging, also referred to as *intrinsic aging,* is a relatively gradual biological process primarily influenced by an individual's genetic profile. It stands in contrast to **extrinsic aging**, which is accelerated by environmental factors, most notably photoaging caused by ultraviolet (UV) radiation. This form of aging, now commonly described as **behavioral aging** [3], can progress rapidly depending on cumulative UV exposure.

Skin aging can be described in various ways, all depending on a reference framework, whether it is a number, a score, or an appearance related to the senescent evolution of the skin profile. Over the years, multiple research teams have developed both quantitative and qualitative tools to measure this phenomenon : in 2009, Vierkötter et al. introduced and validated the SCINEXA score, which distinguishes between intrinsic and extrinsic aging markers [4]. That same year, Dicanio et al. presented a scale to assess both chronological and perceived age, thus distinguishing between the two, based on a visual facial assessment [1]. In 2011, Miyamoto et al. established an empirical skin aging score after a longitudinal study spanning 11 years, based on visual assessments [5]. These contributions converge on the recognition that skin aging results from a constellation of interrelated biological and environmental elements. Most skin properties inevitably deteriorate – sooner or later – under the influence of oxidative stress, often exacerbated by external aggressors such as pollution and sunlight [6].

In 2014, Qu et al. introduced the Skin Youthfulness Index (SYI), grounded in the image-based analysis of 1,505 women's facial profiles [7]. Building upon this foundation, the present communication proposes a Modified Skin Youthfulness Index, SYIm, which leverages a wide array of clinical and biophysical parameters. This enhanced index offers a chronobiological mapping of skin evolution and enables quantification of behavioral rejuvenation in years following anti-aging cosmetic interventions.

The Modified SYIm Index : Defining the Skin's Behavioral Age

Our institute possesses a considerable amount of data from skin measurements in its natural state, i.e., before the application of any cosmetic treatment. These data include both biophysical parameters and clinical assessment scores, and are derived from several hundred healthy Caucasian and Asian women between the ages of 18 and 73. Data collection was conducted over a five-year period, from 2020 to 2024.

We examined the correlation between available biophysical parameters and clinical expert assessments with chronological (or actual) age. Subsequently, we constructed linear and polynomial regression models through a two-step process:

Step 1: Data

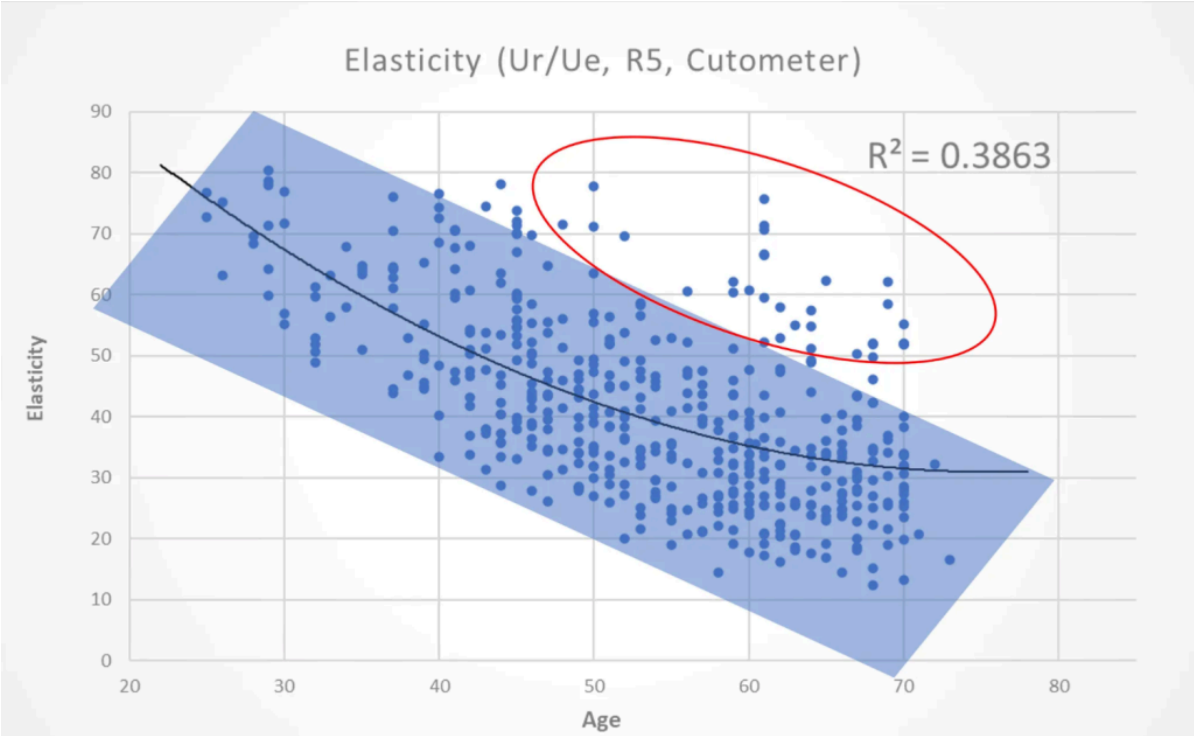

Fig. 1 – Scatter plot (elasticity)

Representation Against Age (Fig. 1)

Example:

- The adjacent plot displays skin elasticity (Ur/Ue, Cutometer R5 parameter; 450 data points) as a function of chronological age.
- This analysis generated a scatter plot (blue shaded area).
- Outliers (red shaded area) were identified and excluded from further analysis.

Step 2: Polynomial Curve Fitting (Fig. 2)

- Data were stratified into ten age groups (25, 30, 35, 40, 45, 50, 55, 60, 65, 70 years). A second-degree polynomial curve was individually fitted to each category.

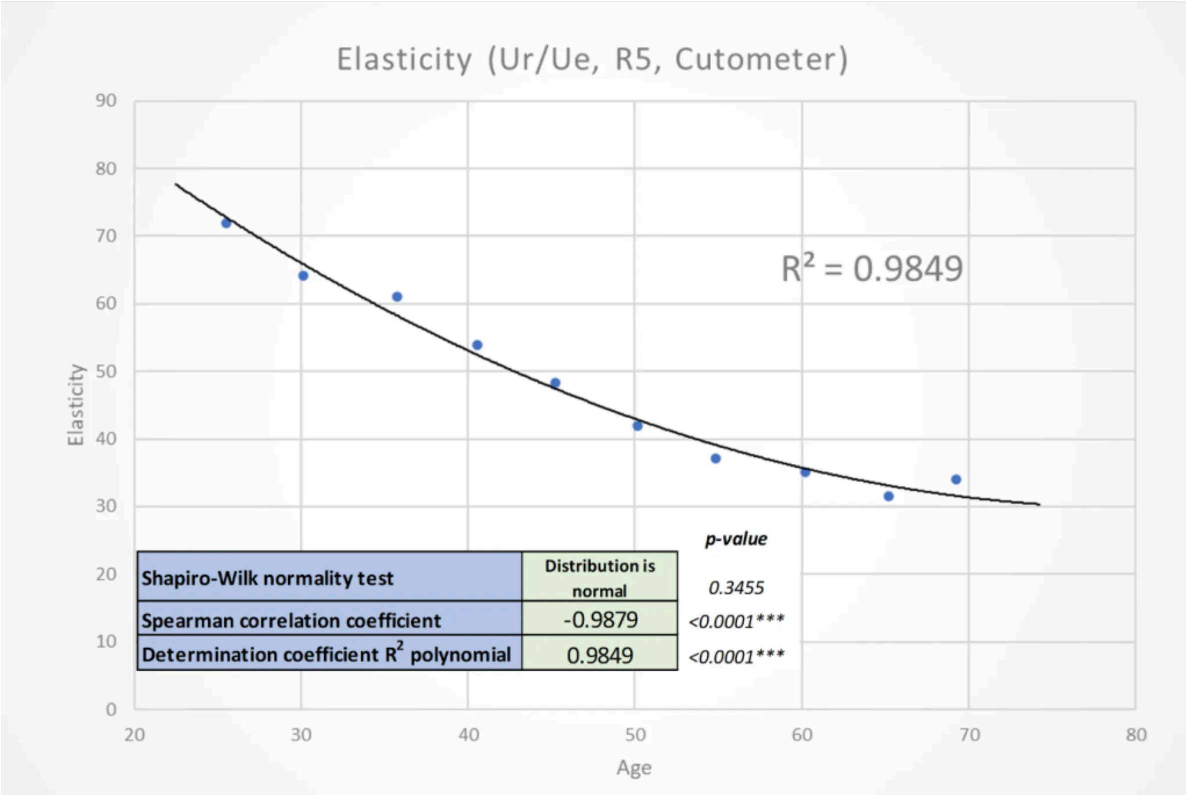

Fig. 2 – Polynomial curve fitting (elasticity)

- The resulting correlation coefficients were consistently high, exceeding 0.95.

The table below presents the results of linear or polynomial regression analyses conducted on 16 selected skin parameters.

Biophysical / clinical parameters	**Nb. of values**	**Coefficient of Determination R^2 (linear or polynomial)**	**Correlation level**	**p-value**
Density	305	0.98	+++	0.0003
Elasticity	450	0.95	+++	< 0.0001
Crow's feet wrinkle severity score (clinical)	258	0.98	+++	< 0.0001
Underneath eye wrinkle depth	233	0.97	+++	0.0001
Luminosity	170	0.96	+++	< 0.0001

Underneath eye wrinkle severity score (clinical)	128	0.95	+++	0.0002
Glycation index	401	0.90	+++	< 0.0001
Crow's feet wrinkle depth	582	0.89	++	0.0128
Nasogenian fold depth	125	0.88	++	0.0150
Hydration	557	0.86	++	0.0001
Sagging volume	228	0.85	++	0.0216
Skin tone homogeneity	263	0.84	++	0.0014
Age spot luminosity	145	0.84	++	0.0018
Firmness	444	0.45	0	0.2988
Transepidermal water loss	235	0.22	0	0.4232
Roughness	87	0.15	0	0.7306

Correlation between the various biophysical parameters measured and skin age
+++ Very strong correlation ++ Strong correlation 0 No correlation

For each parameter, between 87 and 582 individual data points were analyzed and subsequently grouped by age.

To determine which parameters exhibited the strongest age-related correlation, linear and polynomial regression models were applied, alongside statistical testing. Selection criteria focused on the strength of correlation coefficients, including Pearson's r, Spearman's r, and the coefficient of determination R^2 (refer to Table).

Based on these findings, the most relevant skin parameters were consolidated, and the calculation method for the Skin Youthfulness Index (SYI) [7] was implemented. Each parameter was assigned a specific weight within the index according to three criteria :

- its degree of correlation with chronological age
- the amplitude of its measured variation range
- the directionality of its progression over time (increasing or decreasing with age).

The final step in constructing this evaluation framework involved normalizing each parameter on a standardized 0-100 scale, using their respective minimum and maximum recorded values.

The Modified Skin Youthfulness Index (SYIm) is inversely proportional to chronological age. Its main advantage over the original version proposed by Qu et al. [7] lies in its flexibility to accommodate a wide range of parameter combinations (see Table). By selecting between 2 and 13 age-correlated skin parameters – based on linear or polynomial regression patterns – **over 8,000 unique SYIm correlation curves** can be generated.

In cosmetic study protocols, SYIm is calculated from measurements collected before and after product application. This allows researchers to quantify overall skin improvement in percentage terms, which can further be **translated into rejuvenation years** gained, based on the relationship between participant's chronological age and the corresponding SYIm score.

Results

A total of sixteen clinical and biophysical skin parameters were analyzed to establish age-related regression models using both polynomial and linear methods. The curve selection was based on the coefficient of determination (R^2).

- **Seven parameters** demonstrated **strong correlations** with chronological age (**$R^2 \geq 0.9$**, $p \leq 0.0003$) : density, elasticity, crow's feet wrinkle severity score (clinical), underneath eye wrinkle depth, luminosity, underneath eye wrinkle severity score (clinical), and glycation index.
- **Six additional parameters** showed **moderate to strong correlations** (**$R^2 > 0.8$**, $p \leq 0.02$) : crow's feet wrinkle depth, nasogenian fold depth, hydration, sagging volume, skin tone homogeneity, and age spot luminosity.
- The remaining **three parameters** – firmness, transepidermal water loss, and roughness – did not exhibit significant correlations with age (**$R^2 < 0.5$**, $p > 0.05$).

Thirteen age-correlated parameters may be selected to generate SYIm curves (see Table and Fig. 3). These findings reinforce earlier evidence indicating that skin aging is strongly linked to specific biophysical characteristics [1,4,5,7].

Regression curves (Fig. 3) further demonstrate that the earliest signs of cutaneous aging typically manifest around the age of 30, largely driven by the degradation of structural dermal proteins including collagen and elastin [2]. From the age of 40 onward, these age-related changes become increasingly pronounced, as the skin's regenerative mechanisms gradually weaken.

Fig. 3 – Regression curves of the 13 parameters which are correlated with age. **a.** Density, **b.** Elasticity, **c.** Hydration, **d.** Glycation index, **e.** Even skin tone σL*, **f.** Skin Luminance L*, **g.** Age spot luminosity L*, **h.** Sagging volume, **i.** Crow's feet wrinkles (score), **j.** Underneath eye wrinkles (depth), **k.** eye wrinkles (score), **l.** Nasogenian fold (depth), **m.** Crow's feet wrinkles (depth)

Pigmentation-related parameters also indicate that photoaging may begin as early as the third decade of life. This observation aligns with prevailing evidence that chronic exposure to ultraviolet radiation accelerates skin aging by inducing hyperpigmentation and contributing to the deterioration of structural components.

In contrast, parameters such as skin firmness, transepidermal water loss (TEWL), and roughness did not exhibit statistically significant correlations with chronological age. This finding is consistent with prior studies [8,9], which suggest that these features are primarily influenced by age-independent physiological factors, such as cutaneous blood flow and core body temperature [9].

Application of the Modified Skin Youthfulness Index (SYIm) to Cosmetic Studies

Following the identification of the most age-relevant skin parameters (see Table), combinations ranging from **2 to 13 variables** can be used to compute the Modified Skin Youthfulness Index (SYIm) (Fig. 2).

As an illustrative case, an 8-week clinical study evaluating an anti-aging facial treatment assessed five specific parameters: skin density, elasticity, crow's feet wrinkles, complexion homogeneity, and hydration.

SYIm scores were calculated at baseline (T0) and end of treatment (T2 months). These results demonstrated a 62% improvement in the index, increasing from 35.5 to 57.6. This enhancement corresponds to an estimated **reduction in apparent skin age of 11 years** (Fig. 4).

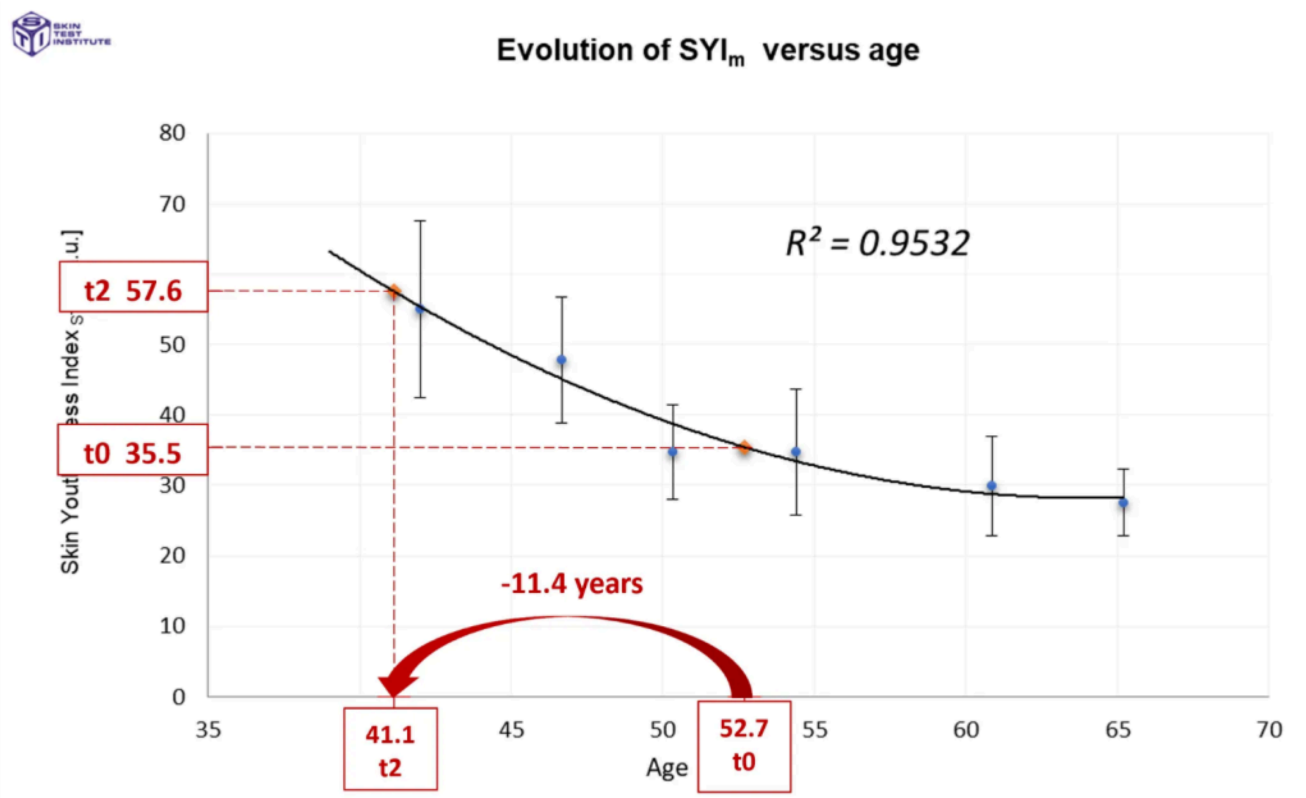

Fig. 4 – Polynomial SYIm correlation curve, computed by combining 5 skin parameters (skin density, elasticity, crow's feet wrinkles, complexion homogeneity, and hydration). Plot versus chronological age.

Conclusion

This development provides a meaningful contribution to the field of cosmetic science and to the broader understanding of skin aging mechanisms:

- **Robust Analytical Framework :** The *Modified Skin Youthfulness Index (SYIm)* offers a reliable and quantitative framework for evaluating *behavioral skin age*, incorporating a wide range of biophysical and clinical parameters. It enables researchers and formulators to express cosmetic efficacy in terms of *apparent rejuvenation years*, thereby making interpretation both intuitive and consumer-relevant.
- **Credible Findings and Meaningful Implementation :** The creation of the SYIm is rooted in our institute's comprehensive *longitudinal data* and analytical expertise. This foundation reinforces the scientific validity of cosmetic innovations and supports substantiated product claims with measurable outcomes.
- **Future Adaptability and Personalization :** Designed as an iterative model, the SYIm algorithm can evolve through the integration of additional datasets and predictive variables beyond chronological age. This

adaptability opens new possibilities for *personalized skin aging assessments* and improved precision in modeling.

Contacts

Alain Béguin – Manager
alain.beguin@skintest.ch
www.skintest.ch
Vanessa Ecarnot – Project and Laboratory Manager
Nataly Mosquera – Scientific Coordinator

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