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"Facial skin elasticity mapping in Chinese females and its comparison to skin softness/stiffness"

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1. Introduction

Being constantly exposed to the environment, the skin - the body's largest organ - undergoes both intrinsic and extrinsic aging processes. Skin aging is characterized by the appearance of wrinkles, loss of elasticity, sagging, and rough texture [1]. Intrinsic aging stems from biological changes over time and involves various histological, physiological, and biochemical alterations[2,3,4]. These changes are influenced by genetic factors such as gender and ethnicity, differences in skin location, and hormonal fluctuations. Mechanically, the skin functions as a layered composite material that becomes structurally unstable under stress, with wrinkle formation being the most visible sign of this instability [1]. As aging progresses, the gradual decline in elastic fibers significantly reduces the skin's flexibility, diminishing its resistance to wrinkling to just one-quarter of its original capacity. This highlights the crucial role that skin elasticity plays in the aging process.

In-depth investigations into the facial skin properties have revealed that the biophysical characteristics of facial skin are highly heterogeneous. At the microscopic level, significant regional differences exist in cellular composition, extracellular matrix distribution, the density of nerve endings and blood vessels. For example, the periorbital skin has a thinner stratum corneum compared to the cheek, and it differs in concentrations of collagen and elastin fibers, which are key structural proteins. These variations contribute to the distinct tactile sensations and mechanical behaviors across facial regions.

Extensive research [5,6] has also demonstrated significant variations in facial skin characteristics among different ethnic groups. These discrepancies can be attributed to a multitude of factors, including genetic backgrounds, geographical environments, lifestyle habits, and long-term evolutionary adaptations. Asian populations, for example, typically possess a thicker stratum corneum and higher melanin content comparing to Caucasians, which makes their skin with enhanced UV resistance. However, this genetic makeup also leads to different patterns of skin elasticity and aging processes compared to European populations.

Skin elasticity, a crucial parameter for evaluating skin aging, plays a vital role in both the skin's physiological function and its aesthetic appearance. It is closely linked to the development of wrinkles and facial sagging. With aging, collagen fibers gradually break down, and elastin fibers undergo degeneration, weakening the skin's elastic support structure. This decline in elasticity impairs the skin's ability to withstand mechanical stress and to return to its original shape, which leads to wrinkle formation and sagging of facial tissues. These visible changes not only alter an individual's physical appearance but also serve as important indicators of skin health and the aging process.

Against this backdrop of current research and practical needs, we have initiated a specialized research project focusing on the facial skin elasticity of Chinese females. The project aims to generate a three-dimensional mapping for facial skin elasticity, filling a research gap specifically in the Chinese female population. Through this work, we hope to gain a better understanding of the unique characteristics of facial skin elasticity in Chinese females and to provide a guidance on the assessment of facial skin elasticity changes when evaluating the efficacy of skin care products.

2. Materials and Methods

2.1. Volunteers and Study Design

A clinical study was conducted at our laboratory in Shanghai, China. The study was conducted in accordance with the principles of the Declaration of Helsinki. A total of 39 Chinese females, age 18-55, Fitzpatrick phototype II – IV, participated the study. The age of the cohorts was stratified with roughly 1/3 age 18-30, 1/3 age 31-45, and 1/3 age 46-55. Before the experiment, participants were instructed to cleanse their faces using a designated facial cleanser and dry their skin with non-woven paper towels. After the cleaning, subjects waited for 30 min in this environment to stabilize their skin condition before testing. The laboratory environment was maintained at a constant temperature (21°C (± 2°C)) and relative humidity (50 % (±10%), regulated by precision air-conditioning systems designed for human efficacy evaluation experiments.

2.2. Instrumental Evaluation

Skin hydration was recorded through a Corneometer® CM825 (Courage & Khazaka, Köln, Germany) that quantifies (arbitrary units, a.u) the capacitance of the superficial skin layers [7]. Skin elasticity was measured with Cutometer® MP580 (Courage + Khazaka, DE), which uses negative pressure to displace a small section of the skin with a 2 mm-diameter opening probe [8]. The study was conducted 3 successive measurement cycles, under a 200-mbar vacuum. The measurement will last for 14 seconds, during which there will be a 2-second pre-time, followed by 3 cycles of a 2-second on (vacuum) time and a 2-second off (skin release) time. Skin elasticity is assessed by R value: R0, R2, R5, and R7. Skin softness/stiffness was measured using Indentometer® IDM 800 (Courage & Khazaka, Köln, Germany). All instrument measurements were conducted at 12 pre-defined points on the half face (Table 1, Figure 1).

2.3. Data Analysis

All statistical analyses were performed using SPSS 28.0 (IBM, Armonk, US). The Shapiro–Wilk Test was employed to assess the significance of data normality; a significance level (two-tailed) greater than 0.05 indicates a normal distribution. A Pearson correlation analysis was conducted to examine the relationship between the test indicators and age, calculating the Pearson correlation coefficient and generating correlation heatmaps and scatter plots, with a significance level set at $\alpha = 0.05$.

2.4. Image Generation

A computational model was developed (patent filed) to link the bio-instrumental data to their corresponding facial positions and generate a color map. To generate a continuous representation of physiological values across the face, measurements between these points were interpolated using thin-plate spline transforms. This interpolation produced pixel-level values that were then converted into colors to visualize the data. The resulting continuous color maps depicted the distribution of skin elasticity, with deep pink indicating higher elasticity and green representing lower elasticity.

Table 1. Mapping layout, description of the 12 pre-defined facial measurement points.

SITE	DESCRIPTION OF SITE
01	Forehead, central, lower
02	Forehead, left, lower
03	Outer eye canthus
04	Under eye, middle
05	Nasolabial sulcus, top
06	Cheek, middle, oblique
07	Cheek, middle, oblique/lateral
08	Nasolabial sulcus, midpoint
09	Cheek, lower, oblique
10	Cheek, lower, lateral
11	Chin, central
12	Jaw, oblique

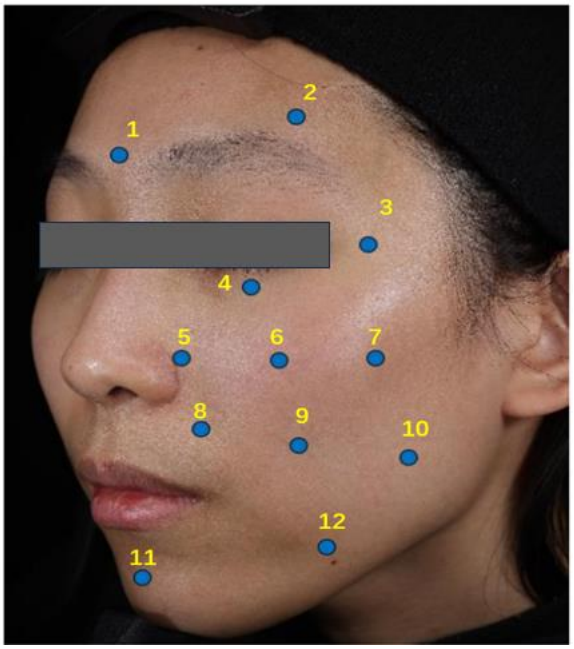

Figure 1 Mapping layout, oblique images of 12 pre-defined facial measurement points.

3. Results

3.1. Skin Elasticity

Table 2 and Figure 2 illustrate the values of skin elasticity obtained on the 12 facial sites from all 39 women, measured using Cutometer® on either the left or right sides of the face according to randomization. The values show some variations at different facial locations.

Table 2. The Mean Skin Elasticity Values on 12 facial sites.

Parameter/ Area	R0	R2	R5	R7
1	0.163	0.652	0.639	0.386
2	0.192	0.665	0.635	0.409
3	0.250	0.615	0.567	0.391
4	0.197	0.638	0.662	0.411
5	0.205	0.707	0.704	0.455
6	0.152	0.632	0.657	0.406
7	0.216	0.667	0.656	0.441
8	0.275	0.752	0.734	0.509
9	0.246	0.794	0.757	0.534
10	0.214	0.747	0.737	0.509
11	0.183	0.625	0.619	0.392
12	0.254	0.759	0.776	0.544

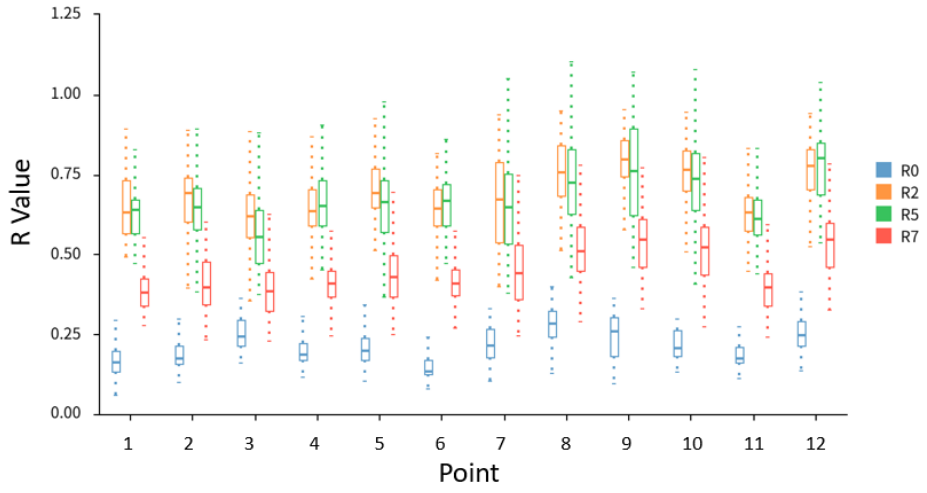

Figure 2 The Mean Skin Elasticity Values on 12 facial sites.

The statistical comparisons of their respective values allowed 4 facial zones (forehead, peri-ocular, cheek, and mandibular region) to being delimited. The regions of the middle (point 7) and lower cheek (point 9) present the largest range of skin elasticity.

In the 12 facial points, no significant correlation was found between R0 and age. In contrast, R2, R5, and R7 exhibited significant negative correlations with age at multiple facial points (Figure 3).

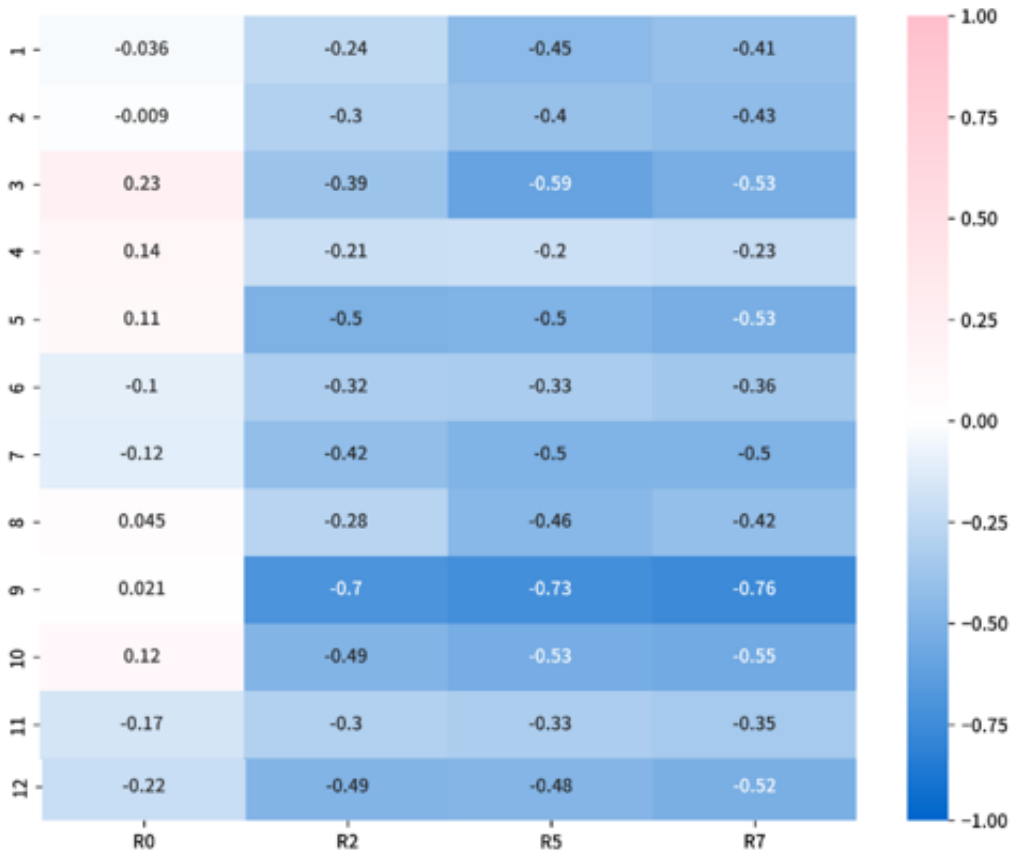

Figure 3 Correlation between Skin Elasticity with Age on 12 facial sites.

The best correlation between age and elasticity is observed at point 9, lower cheek. Notably, substantial disparities in facial elasticity exist between young and elderly women, particularly pronounced in the outer canthal region of the eyes and the lower cheek area (Figure 4). These distinct differences highlight the age-related decline in skin resilience and mechanical properties, which are more evident in these specific facial zones.

3.2. Skin Softness/Stiffness

Skin softness/stiffness was measured using Indentometer IDM800. The vertical displacement of the skin measured by the probe, showed significant positive correlation across most points with R0 value, which is the vertical deformation of the skin under negative pressure (Figure 5). This is an expected result. However, measurement from Indentometer did not show significant correlation with skin elasticity parameters, R2, R5, or R7, nor did it show correlation with age.

3.3. Skin Hydration

Across the twelve predefined facial landmarks, the stratum corneum hydration status, as quantified by Corneometer®, exhibited negligible statistical associations with chronological age, biomechanical parameters of skin elasticity (characterized by Cutometer® - derived R0, R2, R5, R7 indices) and Indentometer - measured softness metrics. These findings suggest that the homeostasis of stratum corneum water content may be regulated by distinct physiological pathways, dissociating it from the age-related decline in dermal matrix integrity and mechanical properties.

Figure 4 Color mapping of Skin Elasticity R Value displayed on a 3D mean face based. Color code for R2 level (0.35–0.9) shown on the scale on the bottom side.

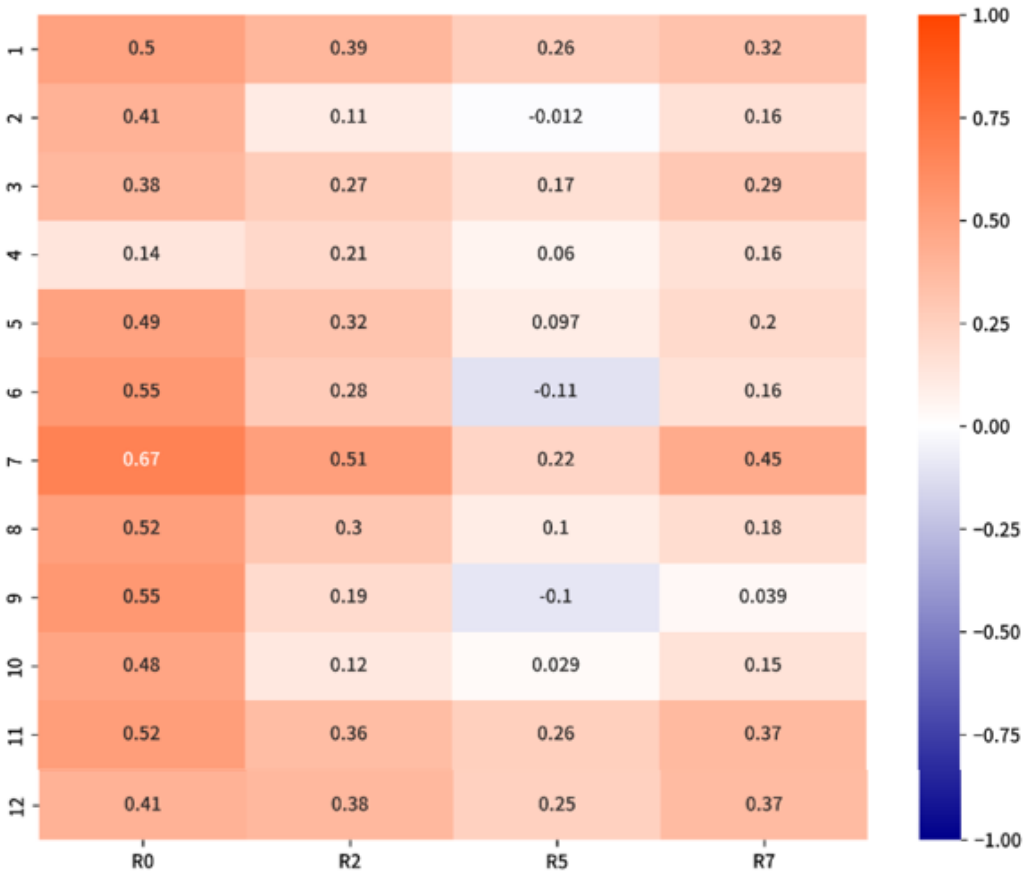

Figure 5 Correlation between Skin Elasticity with Skin Softness/Stiffness on 12 facial sites.

4. Discussion

The present study systematically evaluated age-related changes in facial skin elasticity, softness, and hydration across 12 anatomically distinct facial sites in Chinese female subjects.

Consistent with established literature, significant negative correlations were observed between chronological age and the elasticity parameters R2 (total recovery ratio), R5 (immediate elastic response), and R7 (instantaneous recovery capacity) across multiple facial regions. These findings align with prior reports [9, 10], who demonstrated that reduced R2, R5, and R7 values are key indicators of cutaneous aging. The observed decline in these parameters reflects the progressive loss of dermal matrix integrity and reduced biomechanical resilience associated with chronological aging.

Our study identified two facial regions—crow's feet (point 3, periorbital lateral canthus) and the inferior malar region (point 9, lower cheek)—as exhibiting the strongest correlations between chronological age and skin elasticity parameters (R2, R5, R7) across 12 measured sites. This finding aligns with their unique anatomical vulnerabilities: the periorbital area, characterized by thinner epidermis (0.4–0.6 mm vs. 0.8–1.5 mm in the midface) and dermis, reduced sebaceous gland density, and constant mechanical stress from orbicularis oculi contractions, is inherently prone to early elastin fragmentation and collagen depletion [11,12,13,14,15,16]. Concurrently, the lower cheek, positioned over the malar fat pad and adjacent to the mandibular ligamentous system, undergoes gravitational tissue displacement and progressive degradation of dermal-

epidermal junction (DEJ) components like laminin-332 and collagen XVII, accelerating volume loss and sagging [14,16]. These regional susceptibilities are rooted in the structural and functional properties of the DEJ, a specialized basement membrane comprising collagen IV, VII, laminin-5, and integrins that mediates epidermal-dermal adhesion and mechanical stability [17]. In the periorbital region, the combination of thin skin and repetitive facial expressions exacerbates DEJ weakening by disrupting elastin-collagen networks and increasing matrix metalloproteinase activity, leading to shortened rete ridges and a flattened DEJ morphology [14,17]. In the lower cheek, gravitational forces amplify adipose tissue remodeling and DEJ component breakdown, impairing tissue cohesion and accelerating structural decline [18,19]. Both processes converge on reduced biomechanical resilience, manifesting as age-related elasticity loss unique to these sites. The identification of these hyper-responsive regions carries critical implications for dermatological research and anti-aging innovation. First, their sensitivity to subtle dermal matrix changes—predating overt morphological aging—positions crow's feet and lower cheek as ideal biological markers for detecting early aging signs, enabling proactive intervention strategies. Second, their heightened responsiveness to mechanical stress and topical penetration makes them superior test sites for evaluating anti-aging formulations. By focusing on these regions, researchers can enhance statistical power in efficacy trials, potentially reducing sample sizes while improving detection of treatment-induced improvements in skin elasticity. This targeted approach addresses a key limitation in current protocols, which often rely on less age-sensitive areas (e.g., forehead, nasal dorsum).

Our study also revealed that the periorbital region (points 3 and 4) exhibited significantly diminished values for R2, R5, and R7 when compared to the lower cheek region (points 9 and 10). This can be primarily attributed to two key factors: anatomical vulnerability, and mechanical stress patterns. The periorbital skin is thinner (0.3–0.5 mm) compared to the lower cheek (0.5–1.0 mm), with sparser sebaceous glands and minimal subcutaneous fat. Unlike the lower cheek, which benefits from the cushioning provided by the malar fat pad, the periorbital region lacks this supportive layer. This thinness makes it more susceptible to mechanical damage. Periorbital region is subjected to repetitive contractions of the orbicularis oculi muscle, which occur over 100,000 times daily. These high-frequency movements, such as blinking and frowning, generate significant mechanical stress. This stress leads to fatigue-driven fragmentation of elastin fibers and increased activity of matrix metalloproteinases (MMPs) [20,21], which in turn accelerates the degradation of collagen.

5. Conclusion

This study systematically characterized facial skin elasticity in Chinese females across 12 anatomically defined facial sites, revealing significant regional and age-related variations. Key findings include the identification of the lower cheek (e.g., point 9) as the region with the highest skin elasticity, attributed to its thicker dermis, supportive malar fat pad, and stable dermal-epidermal junction (DEJ), while the periorbital area (e.g., point 3) exhibited the most pronounced age-related elasticity decline due to thin skin, and high-frequency contractions of facial expression muscles. Elasticity parameters R2, R5, and R7 showed significant negative correlations with age, particularly in the lower cheek and periorbital regions, reflecting progressive loss of dermal matrix integrity and mechanical resilience. Skin softness/stiffness and hydration demonstrated minimal association with elasticity or age, highlighting distinct regulatory pathways for these properties. These results deepen our understanding of Chinese female

facial skin biomechanics, identify vulnerable aging-prone zones, and provide a scientific foundation for developing targeted anti-aging strategies and optimizing skincare product evaluations by focusing on regions with high sensitivity to age-related changes.

6. References

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