International Journal of Cosmetic Science

International Journal of Cosmetic Science, 2010, **32**, 241–245 doi: 10.1111/j.1468-2494.2009.00562.x

Review Article

High resolution skin colorimetry, strain mapping and mechanobiology

C. Devillers*, C. Piérard-Franchimont*, A. Schreder†, V. Docquier† and G. E. Piérard*,†

*Laboratories of Dermatopathology and †Skin Bioingineering and Imaging, Department of Dermatopathology, University Hospital of Liège, BE-4000 Liège, Belgium

Received 21 April 2009, Accepted 6 September 2009

Keywords: langer's line, mechanobiology, melanocyte, skin colour, strain mapping

Synopsis

Skin colours are notoriously different between individuals. They are governed by ethnicities and phototypes, and further influenced by a variety of factors including photoexposures and sustained mechanical stress. Indeed, mechanobiology is a feature affecting the epidermal melanization. High-resolution epiluminescence colorimetry helps in deciphering the effects of forces generated by Langer's lines or relaxed skin tension lines on the melanocyte activity. The same procedure shows a prominent laddering pattern of melanization in striae distensae contrasting with the regular honeycomb pattern in the surrounding skin.

Résumé

Il existe de grandes différences de couleur de peau selon les individus. Les nuances sont sous la dépendance des caractères ethniques et des phototypes, et elles sont de plus influencées par d'autres facteurs incluant les photoexpositions et les contraintes mécaniques répétées. De fait, la mécanobiologie affecte la mélanisation épidermique. La colorimétrie par épiluminescence à haute résolution révèle les effets de forces générées par les lignes de Langer ou les lignes de tension cutanée au repos sur l'activité des mélanocytes. Le même procédé révèle une apparence zébrée dans les vergetures distincte de l'aspect en nid d'abeille dans la peau avoisinante.

Correspondence: Gerald Piérard, Department of Dermatopathology, University Hospital of Liège, BE-4000 Liège, Belgium. Tel.: +32 4366 2408; fax: +32 4366 2976; e-mail: gerald.pierard@ulg.ac.be

Introduction

Skin colours show wide interindividual differences. They depend on genetic factors (ethnicities, phototype), environmental factors (suntanning) and local cutaneous factors (scar, striae distensae, frictions). In addition, skin colours show large variations according to the body sites. Even on a small spot (±1 cm^2) dedicated techniques may reveal some heterochromy.

Instrumental assessments of skin colours using dedicated metrological devices result in more objective, reproducible and quantitative information than visual scoring only [1]. Skin colour is conveniently measured instrumentally using reflectance methods. Reflectance colorimetry takes advantage of the CIEL*a*b* standardized system in the L*a*b* colour space notifications [1, 2]. Value L* is expressed on a scale ranging from 0 for black to 100 for white. The positive values a* and b* in the 0–100 range indicate two perpendicular colour axes, with a* corresponding to the red hue and b* to the yellow hue. Differences in colours between the target and the reference areas are calculated using a subtraction (Δ) between the two corresponding figures of the same colorimetric parameter (ΔL*, Δa*, Δb*). Any positive Δ value indicates that the colour under consideration is more pronounced on the target area than that on

the reference area. The overall difference in colour is given by ΔE^* ab following: $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$.

Spectrophotometry is another colorimetric system exploring either the whole light spectrum or the narrow bands [1, 3]. Regular spectrophotometers available in clinical settings typically derive the quantification of the colours related to haemoglobin (E: erythema index) and melanin (M: melanin index).

High-resolution epiluminescence colorimetry

Epiluminescence observations under oil immersion are conveniently performed on any part of the skin according to the regular procedure designed for examining melanocytic neoplasms. First, photographs are taken in a controlled procedure using a special camera (Dermaphot®, Heine Optotechnik, Hersching, Germany). Second, standardized comparative reflectance colorimetric assessments are performed on the photographs using a Visi-Chroma® VC100 (Biophotonics, Lessines, Belgium). This computer-assisted device allows to measure colours in the $L^*a^*b^*$ system of tiny circumscribed areas defined on a computer screen by the observer [4]. Comparative assessments are made on an individual basis from each single photograph to overcome any colour variation during the printing process.

Skin mechanobiology and cell tensegrity

From an engineering viewpoint, human skin is a load-transmitting material. In particular, skin of any part on the body is subjected to variable intrinsic mechanical tensions oriented along specific directions named Langer's lines or relaxed skin tension lines, according to the body posture [5–10]. These oriented tensions are responsible for mechanical anisotropy governed by the fibrous architecture of the dermis, particularly collagen bundles [6]. They affect a series of aspects of skin biology. Indeed, the ability of skin to withstand and transmit loads represents one major aspect of mechanobiology. Mechanotransduction from the dermis to the epidermis is possible through the basement membrane.

Any force generated by or applied to the skin transduces information to cells that may in turn respond to it and alter their tensegrity [11–13]. The effects of mechanobiology are particularly evidenced in fibroblasts, dermal dendrocytes, keratinocytes and melanocytes [14, 15]. When the latter cells are stimulated, the force orientations are conveniently revealed using dermoscopy, particularly in people of darker skin complexion [4, 16].

Ultrasound shear wave propagation in the skin

Subtle differences in skin firmness and in mechanical anisotropy are possibly assessed non-invasively by measuring the speed of propagation of ultrasound shear waves in the skin [8, 9, 14, 17]. The velocity increases when the skin is put under tension. Accordingly, this procedure is conveniently used to reveal the orientation of skin tension lines, and to objectivate the mechanical anisotropy in a multidirectional mapping [11, 12]. In practice, resonance running time measurements (RRTM) are recorded in arbitrary units using the Reviscometer® RVM 600 (C+K Electronic, Cologne, Germany) [8, 9, 14]. The probe contains two piezo-electric transducers. When applied to the skin under controlled pressure, one transducer emits ultrasound shockwaves, and the second serves as a receiver. It is expected that the ultrasound waves propagate differently according to the viscoelasticity of the skin or any other material under investigation [17]. The interval time taken by the waves to travel from the transmitter to the receiver is inversely proportional to the mechanical tensions inside the skin. Measurements are performed at each test site in four directions. With regard to the orientation of the primary axis oriented along the longitudinal axis of the body, the three other measurement directions are oriented at angles of 45°, 90° and 135° respectively. A ring is affixed to the skin to hold the probe exactly at the same site while positioning it at the different angles.

Relaxed skin tension lines, Langer's lines and their colours

Dermoscopical examination of normal skin reveals alveolar or honeycomb networks dictated by the epidermal rete ridges [18]. Indeed, melanin makes the rete ridges visible under epiluminescence examination. The epidermal rete ridges sketch out an alveolar pattern, the inside portion of which is

occupied by dermal papillae. The colour difference is not because of variations in melanocyte density, but rather of the cumulative amount of melanin in the deeper layers of the epidermis. On top of dermal papillae, the melanized epidermal layers are parallel to the plane of the dermoscopical visualization. In contrast, in the epidermal rete ridges, these layers are almost vertically oriented. Hence, the observation cumulates the melanin content on a thicker amount of melanosome-laden keratinocytes [10].

It is acknowledged that discrete mechanical forces applied parallel to the skin surface have an impact on the three-dimensional aspect of the dermo-epidermal junction [9]. The epidermal rete ridges oriented perpendicularly to the direction of the force become smooth and show a trend to flatten, thus decreasing their colour intensity on the dermoscopical examination. In contrast, the rete ridges parallel to the force deepen both their structure and the pattern of dermoscopical hue.

In addition, the melanocyte mechanotransduction and activation [13, 16, 19] could further explain the typical laddering melanotic pattern related to the relaxed skin tension lines. Indeed, it has been shown that mechanical pressure and tension induce melanin formation by human melanocytes both in culture [19] and *in vivo* [13, 16]. In physiological conditions, the melanization process could theoretically be boosted in the epidermal rete ridges oriented in the direction of lower RRTM values. To be clinically relevant, the tension-related activation of melanin synthesis should be accompanied by a facilitated transfer of melanosomes to keratinocytes. As a result, skin anisotropy becomes readily visible.

Striae distensae and their colours

Striae distensae, also known as stretch marks, are the result of the failure of the dermis to sustain intrinsic mechanical forces. They represent common lesions affecting almost half of adolescents and young adults, especially pregnant women. The shape of lesions is linear or fusiform, with variable length. Their surface is often smooth and tense when striae are recent. Older lesions tend to become crumpled and atrophic, giving the sensation of vacuity at palpation. They are hairless and no sweat or sebum excretion seems present.

In striae distensae, both the structure and mechanical functions of the dermal fibrous networks are altered. Ruptures supervene in the direction where the tissue is the weakest to sustain the mechanical stress. As a result, the long axis of striae distensae is orientated along the skin tension lines, and the damages resulting from the rupture occur in the direction normal to the long axis of the striae. The forces responsible for this process are generated by factors distending the dermis, such as fat expansion when gaining weight, visceral pressure during pregnancy, muscular hypertrophy and movement-related skin extension.

Striae distensae show diverse colours [4, 16]. On white skin, many striae distensae look reddish at first and finally turn white. However, the colour palette is broader. The clinical appearance of the striae distensae shades is influenced by the subject typology because the human eye detects colour differences between lesional skin and its surrounding area. The best identified hues are whitish and iridescent (striae albae), erythematous (striae rubrae), bluish (striae caeruleae) and blackish (striae nigrae). Striae caerulae are specifically encountered in subjects under prolonged corticotherapy. Striae nigrae are identified in subjects of dark complexion. The microanatomy support of striae distensae colours appears to be a combination of variations in microvasculature size and melanocyte activity.

The histological presentation of striae distensae, irrespective of their type, usually shows some degree of epidermal atrophy and flattening of the rete ridges. Ultrastructural changes have been described in melanocytes. In recent striae, intercellular oedema is present between melanocytes and keratinocytes. Melanocytic damages present as mitochondrial vacuolization and melanogenesis reduction. In older striae, melanocytes appear

Figure 1 Laddering pattern of skin colours in striae distensae.

reduced in number and melanogenesis looks abated.

In recent stretch marks when cutaneous tensions are still prominent, a laddering pattern of hypermelanosis becomes prominent (Fig. 1). Such observations may result from ethnicity-related factors allowing black skin to show peculiar aspects under dermoscopy. The dermal remodelling is associated with a loss in the dermo-epidermal relief and with leucoderma appearing secondary to a decreased number of melanocytes. In the following evolutive step, tissue relaxation probably abates the mechanobiological stimulus, thus leading to a fading shade of the striae distensae.

The observation of striae nigrae reveals the deformation and distension of the regular alveolar structure. Epidermal rete ridges are orientated along the axis of maximal intrinsic tension. In addition, melanin pigmentation is increased in these structures (Fig. 2). In time, the pigmentation fades, leading to the typical aspect of striae albae. These changes most probably result from mechanobiological mechanisms as melanocytes are affected by mechanical forces [13, 16, 19]. For instance, friction sites are often hyperpigmented.

A wide range of variation in skin shades exists both in the striae distensae and the surrounding uninvolved skin. It is noteworthy that the ratio between the L^* and b^* values is strikingly different in the two sites. However, the differential colour parameters ΔL^* and Δb^* appear significantly correlated when comparing striae distensae and the uninvolved skin. This indicates that the changes in melanin content affect in concert the yellowish aspect and the dark complexion in darker skin people.

Figure 2 Epiluminescence observation of the melanotic laddering pattern in a stretch mark compared with the regular honeycomb pattern in the normal-appearing surrounding skin.

Conclusion

Skin colour determinations shed some light on one clinical expression of skin tension lines. Dermoscopy in patients of darker complexion identifies the lines with higher intrinsic skin tension, probably at risk of developing striae distensae and abnormal scarring following dermatological and plastic surgeries.

Thus, both skin typology and melanocyte mechanobiology play prominent roles in skin colours. Dermoscopy takes advantage to show prominent differences in the patterns of melanin distribution in the epidermal rete ridges.

Acknowledgements

This work was supported by a grant from the 'Fonds d'Investissement de la Recherche Scientifique' of the University Hospital of Liège. No other sources of funding were used to assist in the prepartion of this manuscript. The authors have no conflicts of interest that are directly relevant to the content of this reveiw. The authors appreciate the excellent secretarial assistance of Mrs. Ida Leclercq.

References

1. Piérard, G.E. EEMCO guidance for the assessment of skin colour. *J. Eur. Acad. Dermatol. Venereol.* **10**, 10–11 (1998).
2. Nizet, J.L., Piérard, G.E. and Quatresooz, P. Revisiting biothermal effects on erythematous hypertrophic scars during pregnancy. *J. Cosmet. Dermatol.* **8**, 27–31 (2009).
3. Thirion, L., Piérard-Franchimont, C. and Piérard, G.E. Whitening effect of a dermocosmetic formulation: a randomized double-blind controlled study on melasma. *Int. J. Cosmet. Sci.* **28**, 263–267 (2006).
4. Hermanns, J.F. and Piérard, G.E. High-resolution epiluminescence colorimetry of striae distensae. *J. Eur. Acad. Dermatol. Venereol.* **20**, 282–287 (2006).
5. Borges, A.F. Relaxed skin tension lines (RSTL) versus other skin lines. *Plast. Reconstr. Surg.* **73**, 144–150 (1984).
6. Piérard, G.E. and Lapière, Ch.M. Microanatomy of the dermis in relation to relaxed skin tension lines and Langer's lines. *Am. J. Dermatopathol.* **9**, 219–224 (1987).
7. Piérard, G.E. and the EEMCO group. EEMCO guidance to the in vivo assessment of tensile functional properties of the skin. Part 1: relevance to the structures and ageing of the skin and subcutaneous

tissues. *Skin Pharmacol. Appl. Skin Physiol.* **12**, 352–362 (1999).
8. Hermanns-Lê, T., Jonlet, F., Scheen, A. and Piérard, G.E. Age- and body mass index-related changes in cutaneous shear wave velocity. *Exp. Gerontol.* **36**, 363–372 (2001).
9. Nizet, J.L., Piérard-Franchimont, C. and Piérard, G.E. Influence of body posture and gravitational forces on shear wave propagation in the skin. *Dermatology* **202**, 177–180 (2001).
10. Quatresooz, P., Hermanns, J.F., Hermanns-Lê, T., Piérard, G.E. and Nizet, J.L. Laddering melanotic pattern of Langer's lines in skin of colour. *Eur. J. Dermatol.* **18**, 575–578 (2008).
11. Ingber, D.E. Tensegrity: the architectural basis of cellular mechanotransduction. *Ann. Rev. Physiol.* **59**, 575–599 (1997).
12. Silver, F.H., Siperko, L.M. and Seehra, G.P. Mechanobiology of force transduction in dermal tissue. *Skin Res. Technol.* **9**, 3–23 (2003).
13. Quatresooz, P., Hermanns, J.F., Paquet, P. and Piérard, G.E. Mechanobiology and force transduction in scars developed in darker skin types. *Skin Res. Technol.* **12**, 279–282 (2006).
14. Hermanns-Lê, T., Uhoda, I. and Piérard-Franchimont, C. Factor XIII a-positive dermal dendrocytes and shear wave propagation in human skin. *Eur. J. Clin. Invest.* **32**, 847–851 (2002).
15. Quatresooz, P., Hermanns-Lê, T., Ciccarelli, A., Beckers, A. and Piérard, G.E. Tensegrity and type 1 dermal dendrocytes in acromegaly. *Eur. J. Clin. Invest.* **35**, 133–139 (2005).
16. Piérard-Franchimont, C., Hermanns, J.F., Hermanns-Lê, T. and Piérard, G.E. Striae distensae in darker skin types: the influence of melanocyte mechanobiology. *J. Cosmet. Dermatol.* **4**, 174–178 (2005).
17. Vexler, A., Polyansky, I. and Gorodetsky, R. Evaluation of skin viscoelasticity and anisotropy by measurement of speed of shear wave propagation with viscoelasticity skin analyzer. *J. Invest. Dermatol.* **113**, 732–739 (1999).
18. Hermanns, J.F., Hermanns-Lê, T. and Piérard, G.E. Faint innate hypomelanotic spotting in black skin. *Eur. J. Dermatol.* **17**, 352–354 (2007).
19. Bernd, A., Ramierez-Bosca, A., Görmar, F.E., Bereiter-Hahn, H. and Holzmann, H. UVA/B and mechanical pressure induce melanin formation by human melanocytes in culture. *Eur. J. Dermatol.* **2**, 450–451 (1992).