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Chapter 4

Skin Color Types and Indian Skin Characteristics

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INTRODUCTION

Defining Indian skin as "Asian skin" or "skin of color" may lack of accuracy[1] although India clearly pertains to Asia geographically. The Indian population shows a remarkable diversity with more than two thousand ethnic groups. In addition, great variations exist in terms of climate, diet and social parameters within the country. In this context, Indian skin shows a wide variability in color as well as some specificities. In particular pigmentary disorders are a major concern in India; of a great psychologic impact upon quality of life.[2]

Surprisingly, very few data are available on skin color diversities in India. Few studies specifically dedicated to Indian population have been performed to date. This chapter will mainly focus on a large typological study conducted in 2011, on 1,204 Indian women from different ages and different cities in India, Mumbai, Kolkata, Chennai and New Delhi.

INSIGHTS ON INDIAN SKIN COLOR BASED ON GENOME WIDE STUDIES

The evolutionary history of Indian ethnic groups and subsequent migration from central Asia, west Asia and southern China has resulted in a rich mosaic of socio-cultural, linguistic and biological diversities that also reflects in the variety of skin colors present on the Indian subcontinent. Broadly, Indians belong to Austro-Asiatic (AA), Tibeto-Burman (TB), Indo-European (IE) and Dravidian (DR) language families.[3] Distinct religious communities, hierarchical castes and sub-castes, and isolated tribal groups that comprise the people of India remain largely endogamous. The most comprehensive survey of genetic variations in India so far analyzed 405 single nucleotide polymorphisms (SNPs) in 55 groups and identified distinct clusters correlated to language and geography.[3]

Association between human skin color and genetic factors arose with the finding that zebrafish with a variation in the *SLC24A5* gene is a golden color and with fewer, smaller and lighter melanosomes than normal zebrafish.[4] Humans also harbor the *SLC24A5* gene and consulting HapMap, a free publicly accessible database of human genetic polymorphism, revealed that people of European ancestry as compared to Africans and East Asians have slightly different versions of the *SLC24A5* gene Africans and East Asians. Since, the genetic basis that underlies normal variation in the pigmentary traits of skin or hair and eye color has been the object of intense research aiming at understanding the diversity observed between and within human populations. Several approaches were undertaken, such as comparative genomics of candidate genes, identification of the human genome under positive selection and the genome-wide and specific allele association studies. Findings from these studies point towards independent selection for different pigmentation gene sets between Asian, European and African populations.[5]

At phenotypic level, human skin color is largely determined by two biological components, melanin and hemoglobin, and one major environmental component, that is exposure to sun ultraviolet (UV) rays. In East

Asians, additionally the skin adipose tissue or hypodermis may provide an additional yellowish tinge. A qualitative assessment of skin color variations on the Indian subcontinent represents the variation seen throughout the world. This is indeed reflected by genetic studies on Indian subpopulations. Four genes account for a major component of color variation amongst Indians: *SCL24A5* (ortholog of zebrafish golden), *TYR* (ortholog of mouse Albino gene), *SLC45A2* (ortholog of mouse Underwhite) and *MC1R*.[6,7] These genes have also been implicated in color variation between Europeans and Africans. Light skin in Europeans and dark skin in Africans is due to alternate alleles in the same genes. At least some of the same alleles responsible for this color difference between Europeans and Africans seem being involved in Indians. The *SLC45A2* SNP shows an allelic gradient from north to south in Europe.[5] Does this gradient also exists from North to South in India is a question of much sense. Indeed, a distinct genetic divergence is seen between Ancestral North Indians (ANI) and Ancestral South Indians (ASI) that may also manifest in skin colors of these two populations.[8] The region around the *SLC24A5* gene shows a considerable reduction in heterozygotes suggesting a major selective sweep of this light skinned allele through the population. Light skin in Indians and Central/ Western Eurasians have common origin independent of those in Asians, especially the contribution of *SLC24A5* allele. These results are more indicative of an ancestral origin rather than a selection sweep driven by sun UV-damage. On the other hand, the results also suggest that in South India and Sri Lanka natural selection may keep a low frequency of the 'light alleles', such as *SLC45A2*. Thus genomic variations associated with pigmentation in South Asian population reflect complex phenomenon of ancestral origin, migration and environmental factors.

Functional testing of variant alleles is paramount to connect phenotype correlations with biological differences. For instance, variant *MC1R* alleles show direct correlations between the biochemical signaling properties of the encoded receptor and the red-hair fair skin pigmentation phenotype. Direct testing of a range of clonal melanocyte cultures derived from donor skin tissue characterized for three causal SNPs within *SLC45A2*, *SLC24A5* and *OCA2* (blue-brown eye color) has assessed their impact upon melanin content and activity of tyrosinase. By culminating genetic and functional studies, it is apparent that genes that impact melanosome biogenesis or the melanin biosynthetic pathway are candidates to explain the diversity seen in human pigmentation that would also apply to Indian population.

SKIN COLOR EVALUATION METHODS

Colorimetry is a technology used to quantify color, and so describe objectively the color perception. It is similar to spectrophotometry, but is distinguished by its interest in reducing spectra to the physical correlates of color perception, most often the CIE 1931 XYZ color space tristimulus values and related quantities.

To assess and compare skin color *in vivo* some methods are available using calibration and standardization principles. We do not focus here on clinical tools but on the interest of objective, non-invasive and reproducible instrumental devices. Globally these instruments can be divided into two categories: one, such as Chromameter® or Spectrocolorimeter®, acquires color parameters and the other quantifies color by analyzing digital images in RGB model.[9,10]

Chromasphere® (Fig. 1) is a reference tool[11,12] for facial skin color assessment thanks to its stability, reliability and its capacity to use diffuse lighting systems that faithfully mimic sun natural daylight (CIE illuminant D65). The whole face is illuminated with a homogeneous light. Such

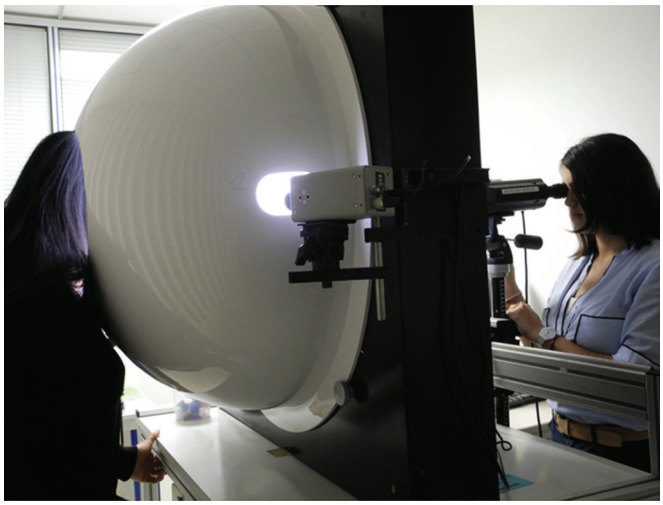

Figure 1: Chromasphere®
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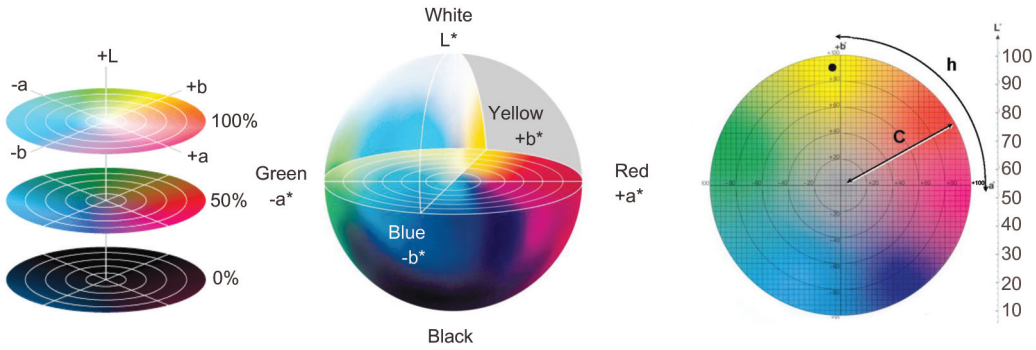

Figure 2: CIE L*a*b* and L*C*h color space

a device is contact-free; avoiding any external pressure that could affect blood flow and induce change in skin color. Combining Chromasphere® with different equipments allows various color characteristics to be quantified.

Calibrated images can be obtained with charge-coupled device cameras, avoiding any drift in digital camera recording and thus allowing the operator to analyze data with different methods. The heterogeneity of skin color can be then assessed with coxellography index approach (co-occurrence matrix). Segmentation and image analysis allow carnation and pigmented spot areas to be detected and separated to obtain various parameters. Spots density, size or color could then be investigated. Meanwhile, colorimetric information is computed to describe complexion and contrasts between pigmented spots and surrounding areas.

Skin color can also be measured with a spectro-radiometer. This kind of device acquires reflectance of skin from 380 nm to 780 nm every 4 nm. The spectrum recorded on the visible field (400–700 nm) is expressed in the CIE 1976 standard colorimetric spaces L*a*b*C*h D65/10° (Fig. 2).

- The lightness L* uses a grey scale and accounts for more or less lightness and more or less darkness.
- The a* and b* are the color-opponent dimensions. These color axes are based on the fact that a color can not be both red and green, or both blue and yellow, because these colors oppose each other. On each axis the values run from positive to negative. On the a-a' axis, positive values indicate amounts of red while negative values indicate amounts of green. On the b-b' axis, yellow is positive and blue is negative. For both axes, zero is neutral grey.
- From the a* and b* values, the angle hue *h* and the chroma C* are calculated. The angle hue *h* correspond to the angle between the a* and b* axis and is the colored coordinate. It characterizes the color from red to yellow within the skin color space.
- The Chroma C* or saturation refers to the pureness or vividness. It refers to the intensity of the hue.

INDIAN SKIN OVERALL COMPLEXION

Color Skin Tone in India as Compared to Other Ethnicities

Previous works indicate that skin color of the Indian population is very diversified,[1,13,14] with phototypes III to VI, types IV and V being predominant.[15] Surprisingly, skin-related typology studies on Indian population are scarce. A few available papers being devoted to colorimetric characterization of Indian women skin and its specificities (age, homogeneities, etc). The differences of skin color across India, and its changes with geographical location were recently investigated.[16] In this article skin colors of 1,195 healthy Indian women from 18 years to 85 years old originating from four cities were quantified using an objective colorimetric tool, Chromasphere®. Results showed a wide diversity of skin color within Indian women: the population covers a large range of skin colors, from very dark to light (Fig. 3).

The skin color of women from other ethnicities was previously evaluated[12,17,18] revealing a worldwide continuum of skin color. The projection of Indian skin

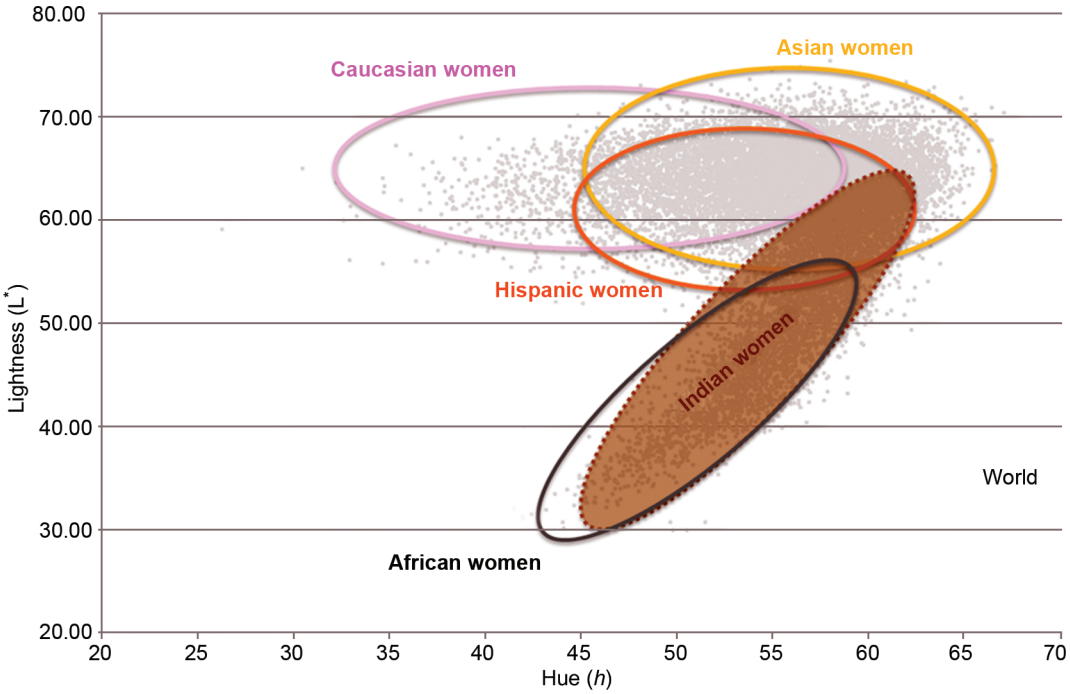

Figure 3: Skin color space in L* *h* plan measured by spectroradiometer in four different clusters of skin color: Caucasian, Asian, Hispanic and African (see Table 1). Projection of Indian women skin color in this worldwide skin color continuum
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color space in this continuum is closed to the one of African women and women from African descent but with a larger range of lightness (Fig. 3). The Indian skin color space indeed overlaps those of Asian and Hispanic women. This data highlights the wide diversity of skin color in India as compared to other ethnicities.

Variation of Skin Color Tone within India: Differences Depending on Geographical Localization

Considering the diversity of climate/environment in India, the impact of geographical location on skin color has to be investigated. Results in Figure 3, arising from a recently published study, cover populations of four cities from north to south (Chennai and Delhi) and from west to the east (Mumbai and Kolkata).[16] Results of this study showed a huge variability in skin color among the four cities, suggesting an environmental impact upon skin color (Fig. 4).

The wider variations in skin color are found in Chennai. Instrumental measurements showed that the women living in this city present the largest hue range as well as the darkest, less saturated and reddest

Table 1: Skin color continuum studies; detailed studied population referring to figure 3

Indian Women (n = 1195)	From Mumbai, Chennai, Kolkata and Delhi
Caucasian Women (n = 2054)	France: Paris Russia: Moscow USA: Chicago/New York
Asian Women (n = 4127)	China: Guangzhou, Shanghai, Beijing Japan: Tokyo Korea: Seoul Thailand: Bangkok France: Paris
Hispanic Women (n = 223)	USA: New York Brazil: Rio Mexico: Mexico
African and Women from African Descent (n = 853)	South Africa: Johannesburg France: Paris (with native of the French West Indies) USA: New York

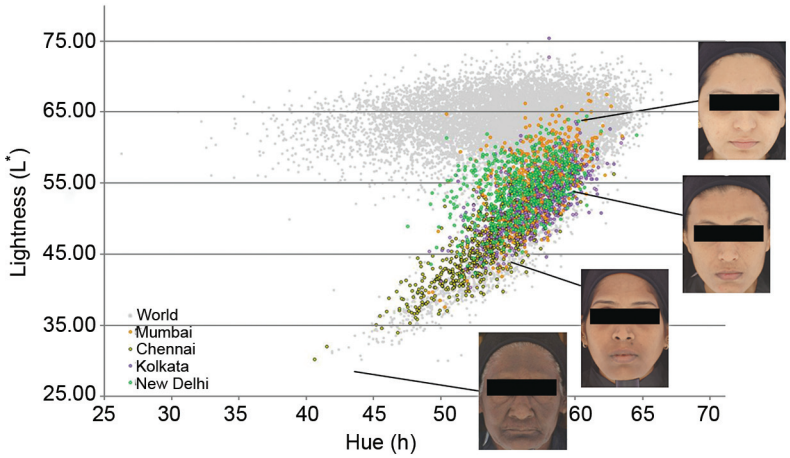

Figure 4: Indian skin tones in four cities: Mumbai, Chennai, Kolkata and New Delhi (lightness by hue) ©L'Oreal Research and Innovation

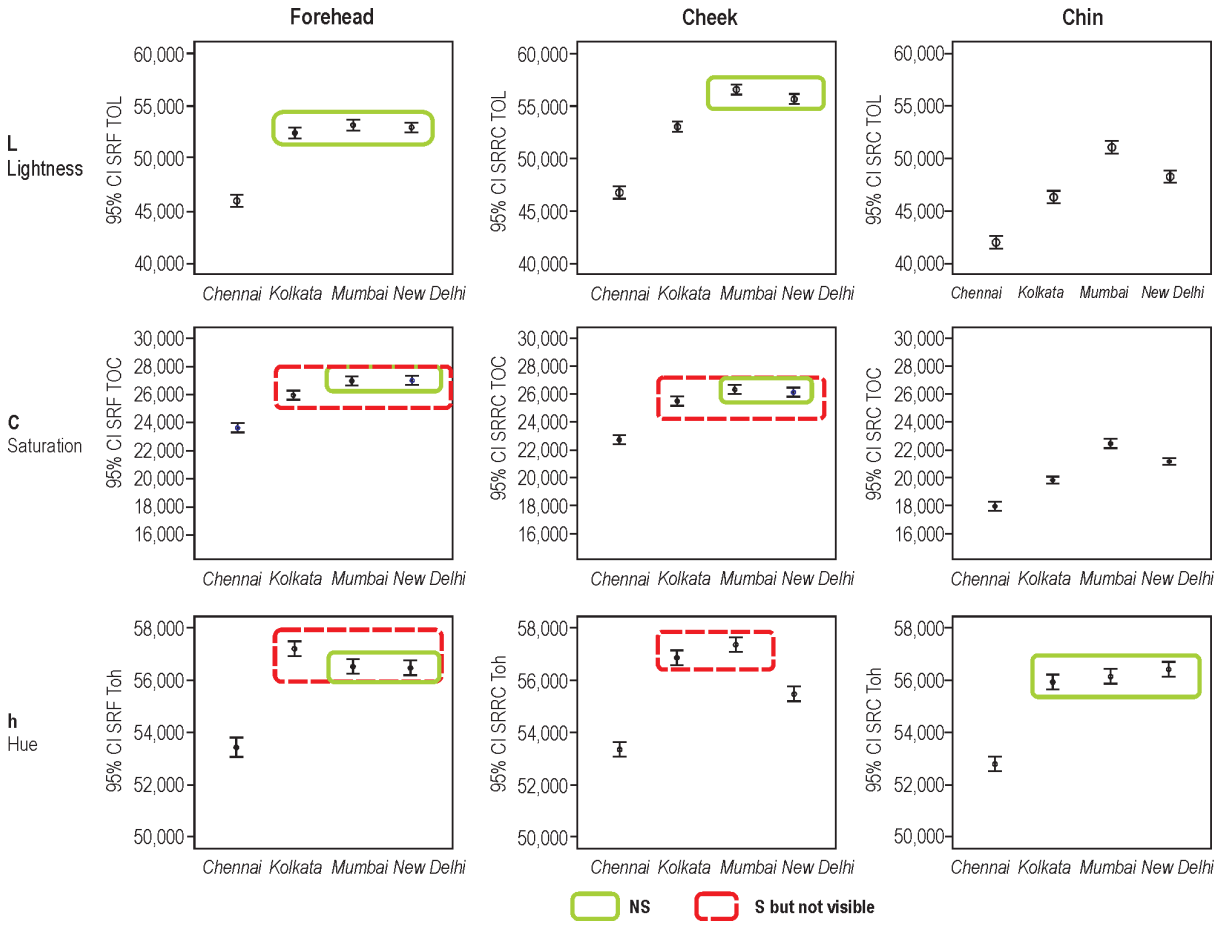

Figure 5: Comparison of skin color parameters per facial area in four Indian cities (Chennai, Kolkata, Mumbai, New Delhi) (n= 1195 women)

Figure 6: Indian skin complexion: Dermatologist assessment
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skin whatever the area of the face (Fig. 5). On a scale of 6 skin complexion types identified in India (Fig. 6), 74% of women skin colors are described as "brown" or "dark brown" by a dermatologist.[16]

The results for the three others cities are roughly similar with some noticeable particularities.

Kolkata shows the largest range of skin lightness and saturation. According to the graphic representation (Fig. 4), there is a strong link between lightness and hue: the darker the skin is, the redder and less vivid (less saturated) it is. Although skin color in Kolkata is quite darker as compared to Mumbai, hue or saturation is similar (Fig. 5). Skin colors of women from Mumbai and Delhi only differ by the hue component: cheeks are redder in Delhi than in Mumbai. Those differences of skin color complexion were confirmed clinically with a same rate (34%) of "medium brown" skin (Fig. 6) but different prevalence of "brown" and "wheatish" skin: 41% of "brown" and 21% of "wheatish" in Delhi versus 10% of "brown" and 45% "wheatish" in Mumbai.[16]

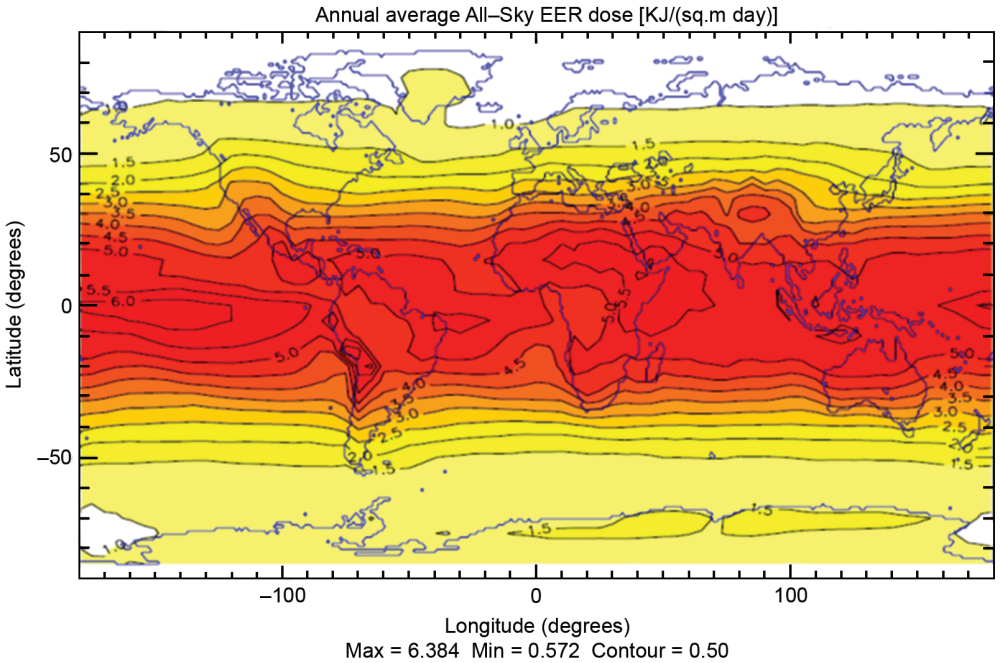

Figure 7: Annual average of sun exposure[19]

The trends observed on cheek or forehead are more pronounced for the chin (perilabial area) (Fig. 5). This area is more discriminant since it allows the four cities to be differentiated in terms of lightness and saturation.

According to these results, it would appear that there is a latitude effect and an impact of the environment (sun UV exposure, life habits, pollution, etc) upon the skin color of Indian women. The skin colors of women from Chennai, located in the South of India, are very different from those of the Northern cities. India could then be split diagonally from South West to North East. The skin colors of the two cities of the East coast are darker whereas the skin colors of the two Western cities are lighter. This difference was also found in another study comparing Calicut and Delhi.[18] Several hypotheses could be proposed to explain this phenomenon. The importance of UV exposure during the year could be considered (Fig. 7). Chennai area indeed undergoes higher sun exposure than other cities.[19] Nevertheless, this hypothesis alone might not suffice to explain the huge variations observed in skin color. This might be also explained by the different flows of migration and the interbreeding of two distinct ancestral lineages: Dravidians and Indo-Europeans.[8]

Evolution of Indian Skin Color with Age

Skin darkening with age has been described in various populations, e.g. a Chinese group living in Chicago as reported by de Rigal et al.[20] However, such age-related changes were not observed in African-Americans, Caucasians, and Mexicans living in the same area.[20] A recent study on Chinese women living in China[21,22] showed a rather linear darkening with age along the life span. Another study conducted in eight Asian cities including two Indian cities (Calicut and Delhi) found that the melanin index increased with age while L* value decreased, indicating that skin darkens with age.[18]

The change in skin color with age in India was deeper investigated in the study previously mentioned.[16] Instrumental measurements showed that overall skin color darkens with age (Fig. 8). By comparing the changes in L* parameter with age between Indian women and women from other countries, it has been highlighted that Indian skin darkens at a different kinetics, i.e. twice slower than Asian skin and slightly faster than Caucasian skin.

But this age effect has different intensity depending on the Indian city (Fig. 9). Chennai is indeed the only city where the age effect is significant in the three color

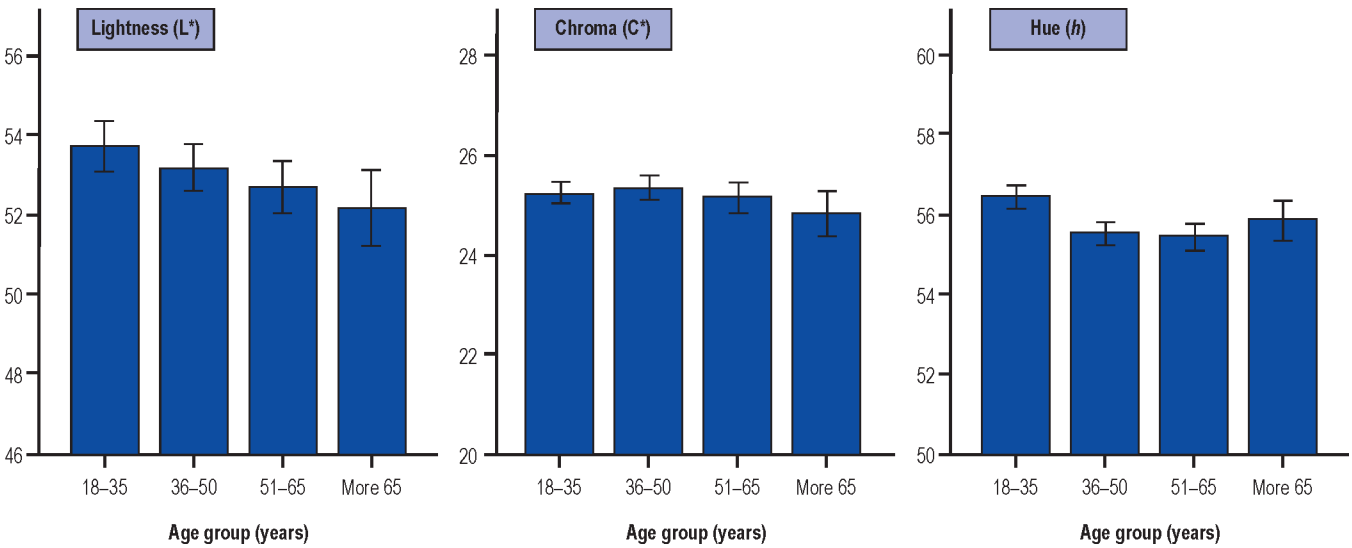

Figure 8: Average skin lightness, Chroma and Hue according to different age groups. Measured on cheek with spectroradiometer® (n = 1195 Indian women)

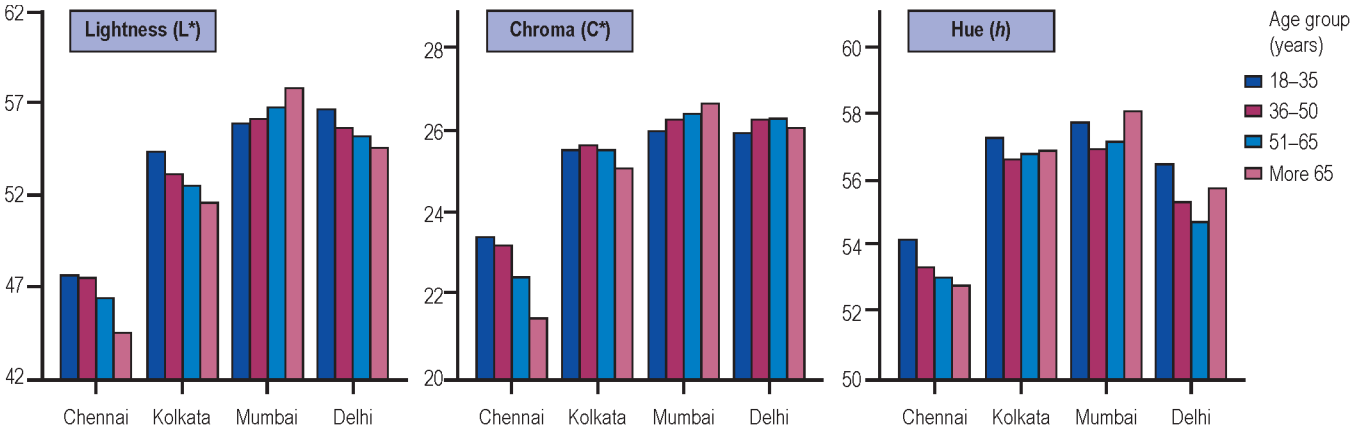

Figure 9: Average skin Lightness, Chroma and Hue according to different age groups in four Indian cities (Chennai, Kolkata, Mumbai, Delhi). Measured on cheek with Spectroradiometer® (n = 1195 Indian women)

parameters with the highest darkening and a skin becoming redder and less saturated with age.

No significant change in skin color was found in Mumbai. Unlike Mumbai, skin color of women from Kolkata and Delhi darkens with age. This difference of age effect between those three cities could be related to the difference of skin color previously observed and by the specific environmental conditions of each city.

The difference of Indian skin color change with age between a rather photo-protected skin area (upper inner arm) and an exposed area (cheek) was also investigated (Fig. 10).[16] Chromameter® measurements showed that after 35 years, the skin becomes slightly fairer with age on the photo-protected area (Lightness increase by 6%), when it becomes barely darker on photo-exposed area (Lightness decrease by 2%). This may account for overall impression of facial darkening compared to the whole body for women, although facial darkening is of a low extent. This has been investigated in other populations in large cohorts of Caucasian's and Korean's (653 Caucasians and 497 Koreans).[23,24] In Caucasians, a significant darkening of exposed areas was observed after 20 years. Amongst Koreans, skin color alteration seems close to that found in the Indian study, the skin color remaining rather stable with age.

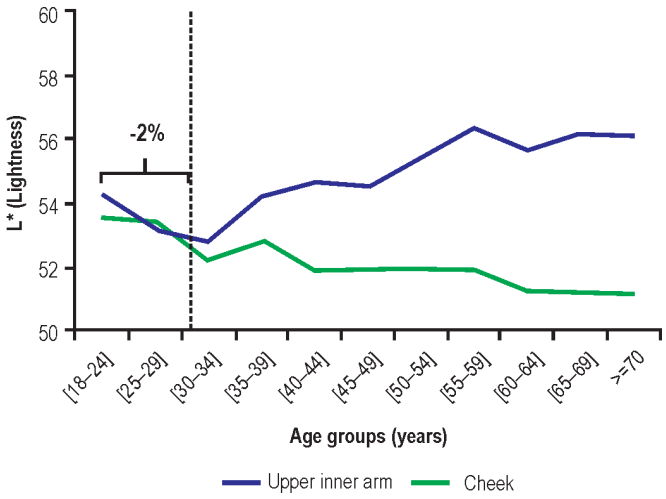

Figure 10: Average skin lightness in age groups (years) measured on cheek (photo-exposed area) and upper inner arm (photo-protected area) (n = 1202)

SKIN COLOR UNEVENNESS IN INDIA

Overall Facial Skin Color Heterogeneity

Another issue concerning Indian skin color has emerged with regard to its heterogeneity. Coxellography index approach allows the overall color heterogeneity of the face to be evaluated taking into account the variations of color (hyperpigmented and hypopigmented spots, telangiectasies), and pores. Results showed that skin color heterogeneity of the cheek increased with age (Fig. 11), which could be explained by an increase in pigmentary disorders and hyperpigmented areas.

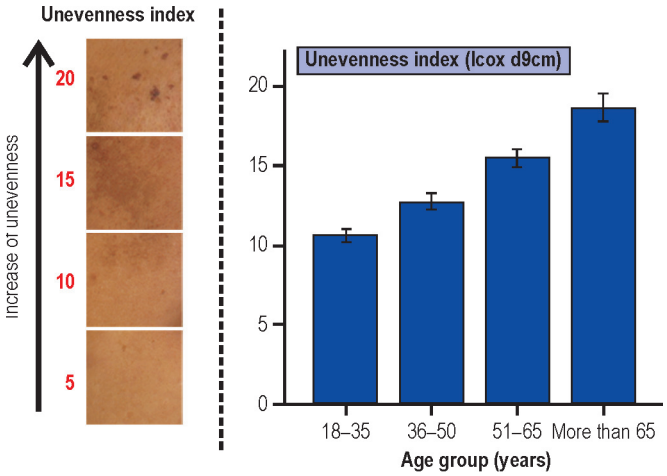

Figure 11: Overall skin color heterogeneity per age group in India (n = 1195)
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Figure 12: Hyperpigmented spots on two Indian women
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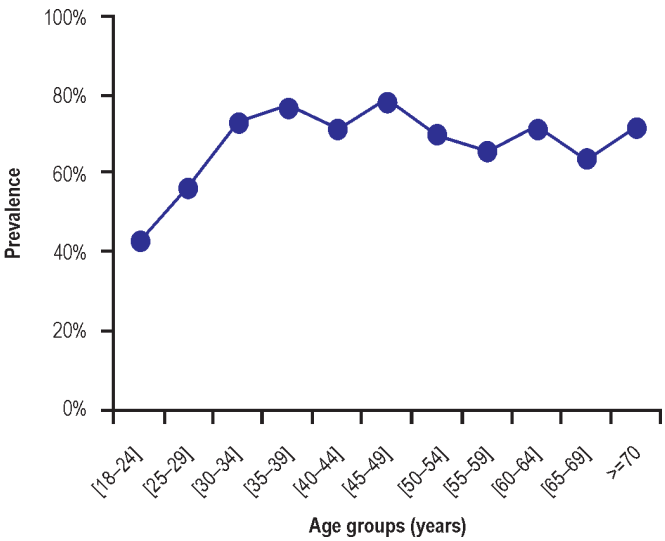

Figure 13: Prevalence of hyperpigmented spots (according to age group) assessed *in situ* by dermatologists (n = 1204)

Pigmentary Disorders

Few studies document the increased frequency of disorders characterized by hyperpigmentation in darker ethnic groups.[25-28] The importance of which is also reported as a frequent concern in Indian population. Some pigmentary disorders have been described in India,[29] hypopigmentary disorders, such as vitiligo, pityriasis alba or versicolor, and also hyperpigmentary disorders, such as melasma and some other facial melanoses.[30-33]

Hyperpigmented Spots

Hyperpigmented spots are a major concern with an early onset and an overall increase with age, well described in some other Asian countries. Several studies conducted in China showed that the early onset of marked pigmented spots is a characteristic of Asian skin aging.[34,35,22] Galzote et al.[18] also observed an increase in mottled pigmentation with age in different Asian populations, India included.

These results were confirmed in the Indian typology study:[16] more than 70% of women over 30 years show more than 10 small hyperpigmented spots on their face (Figs 12 and 13), increasing up to 80% in women over 50 years ($p < 0.0001$). Before 40 years, most of these small spots are post-inflammatory marks, in relation to the high prevalence of acne. From 30 years, dermatologists observed simplex lentigos and actinic lentigines in more than 80% of women, but differentiating them remain difficult. Many seborrheic keratoses were also observed (about 70% of women). Such a high prevalence and early onset of actinic lentigines and seborrheic keratoses (at around 30 years) in India are striking.

Instrumental methods confirmed these results. An individual analysis of pigmented spots with an automatic detection of colored objects revealed no change in the size of pigmented spots with age but an increase in their number and visibility (by contrast with the skin

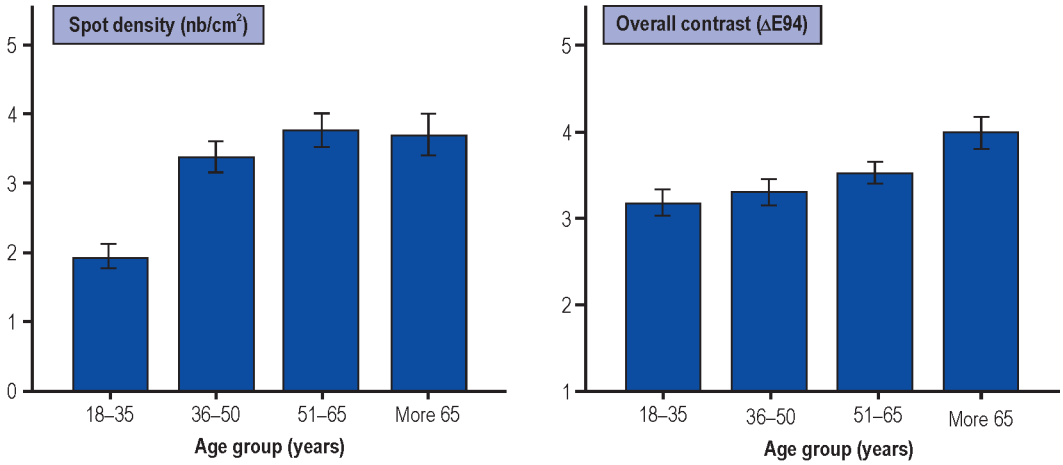

Figure 14: Density and overall contrast of facial spots according to age group in India

complexion). Globally, the spots density increases significantly after 35 years, and shows no significant change after whereas the overall color contrast (ΔE94) between complexion and spots, i.e. the visibility of spots, increases significantly only from 50 years (Fig. 14).

Melasma and Patchily Hyperpigmented Macules

Melasma is a frequently described pigmentary disorder in the Indian population. The worldwide reported prevalence of melasma ranges from 8.8% among Latino females in the Southern United States[36] to 40% in Southeast Asian populations.[37] The Indian typology[16] confirmed the high prevalence of melasma in this country. The average

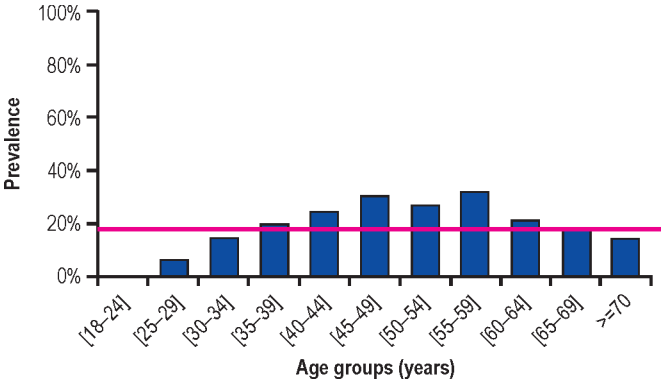

Figure 16: Prevalence of melasma (according to age group) assessed *in situ* by dermatologists (n = 1204)

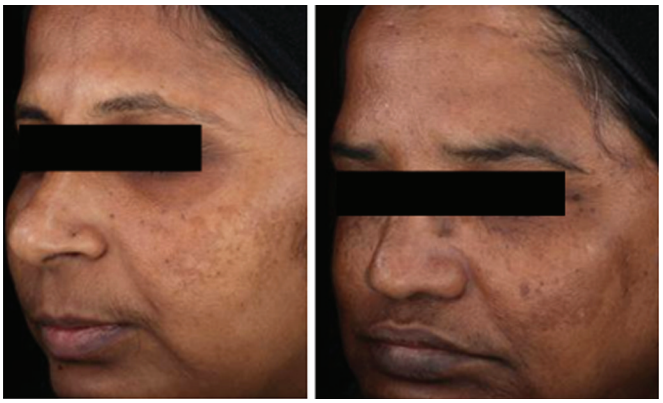

Figure 15: Melasma and dyspigmented macules observed in two Indian women
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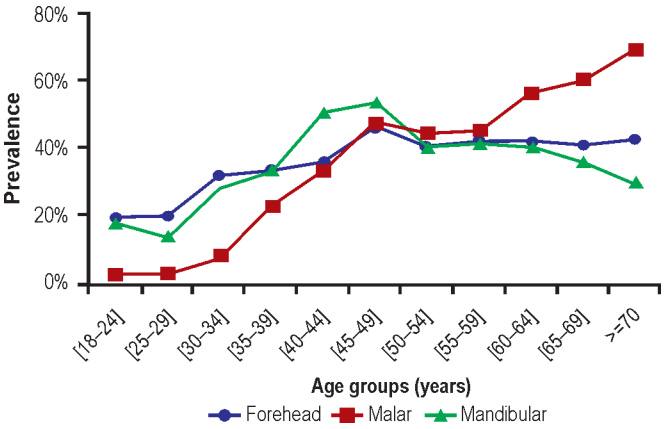

Figure 17: Prevalence of dyspigmented macules on forehead, malar or mandibular area (according to age group) assessed from photographs by dermatologists (n = 1196)

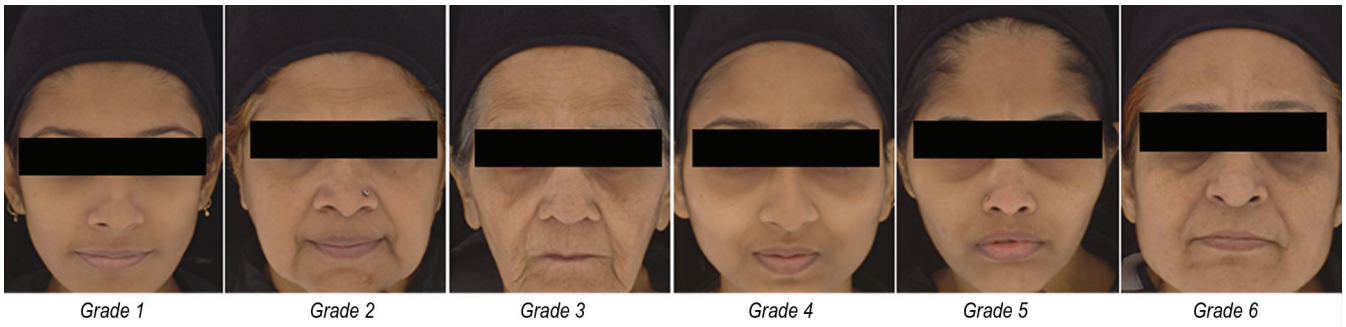

Figure 18: Atlas of dark circles color intensity
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age of women with melasma is 51 years with a prevalence of 19% in the studied population. A peak of melasma prevalence is observed *in situ* by dermatologists in about 30% of women aged from 40 years to 65 years (Figs 15 and 16).

However, melasma alone do not represent all the dyspigmented spread macules observed in this study. Dermatologists' assessments distinguish other ill-defined, patchily hyperpigmented macules on the face which differ from melasma. The prevalence of moderately to severely dyspigmented macules increases with age particularly on the malar area reaching 70% of women ($p < 0.0001$) (Fig. 17). Furthermore, the prevalence of spread macules steadily increases with age, unlike the bell curve distribution of melasma prevalence along life span.

Hypopigmentary Disorders

The prevalence of vitiligo in India is often claimed higher, of a 0.46–8.8% range.[38] But according to a recent review focusing on the prevalence of vitiligo in the general population and excluding studies based on patients of dermatology clinics, the worldwide prevalence of vitiligo ranges 0.5–2%.[39] This appears consistent with the results from Hourblin et al.[16] who reported a low prevalence of vitiligo (0.9%), affecting less than 10% of women. The main diagnoses associated with hypopigmentary disorders were post-inflammatory hypopigmented marks and pityriasis alba. Some city-related effect ($p < 0.0001$) was noticed, with hypopigmentary disorders prevalence varying from 5.2% in Chennai to 15.0% in Mumbai.

Hyperpigmented Areas

Dark Circles

Periorbital melanoses are very common dermatological disorders particularly in India. Despite its frequency, little is known about its etiology and management. Malakar et al.[33,40] describe them as a dark brown to black hyperpigmentation, usually bilaterally symmetrical, and define them as an extension of pigmentary demarcation lines (PDL) of the face. The recent Indian typology confirms the importance of this disorder in India,[16] with more than 50% of concerned women irrespective of age, and up to 80% beyond 35 years old. According to dermatologists' assessment, almost all women have dark circles on upper eyelid and on lower eyelid, of a different

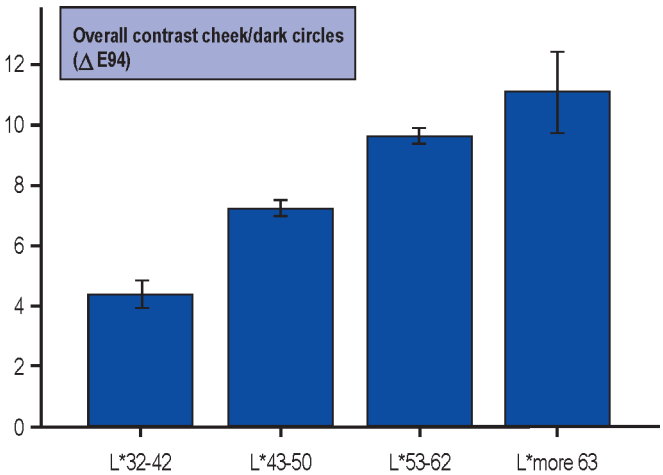

Figure 19: Overall contrast (ΔE94) between cheek and dark circles for each lightness complexion level

intensity with age (Fig. 18). The prevalence of women with moderate to severe dark circles on upper eyelid, increases with age from 50% up to 85%.

These clinical results are confirmed by instrumental measurements which quantify the dark circles color using Spectroradiometer® associated with Chromasphere®. The contrast with the cheek, i.e. their visibility, appears very important. The visibility of dark circles increases with the complexion lightness (Fig. 19); they are logically more visible on the lightest skin.

Facial Pigmentary Demarcation Lines

Pigmentary demarcation lines are physiological abrupt transition lines from areas of deeper pigmentation to lighter areas. They were first classified into five types on the whole body, A through E.[41] Then it was suggested that these lines can also occur on the face and lines F, G and H were added.[32] The facial lines differ from the rest of PDL since they present later, usually around puberty (lines A to E tend to present in early childhood), and they affect males less frequently.[42] The higher proportion of affected females may indicate hormonal influences. Pregnancy is associated with worsening of many pigmentary problems. These lines are almost always bilateral. In some people the lines merge with the periorbital pigmented circle.[40]

Figure 20: Specific hyperpigmented areas on Indian skin. **A**, Lip corners and **B**, Nose bridge
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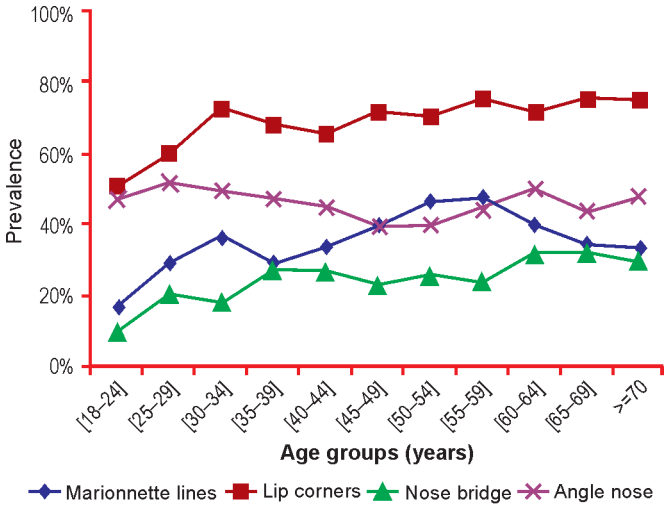

Figure 21: Prevalence of moderately to severely hyperpigmented areas (according to age group) assessed *in situ* by dermatologists (n = 1204)

Other Specificities: Perilabial Pigmentation and Nose Bridge

As previously described,[32] Indian typology confirms that perilabial pigmentation is very frequent in Indian women. About 30% of women of all ages show moderately to severely pigmented upper lip. About 70% of women over 30 years have moderately to severely pigmented lip corners (Figs 20 and 21) whereas about 40% of women over 30 years present moderately to severely pigmented marionette lines.

A distinctive finding was pigmentation of the nose. About 50% of women of all ages showed pigmentation at the angles of the nose. In addition, 25% of women had a hyperpigmented line across the nose (42% of Mumbai women); in some of them, the line was broad and divided the nose into a darker area on top and a lighter area below (Figs 20 and 21). The prevalence of this disorder increased with age from 10 to 30%. Recent studies have described linear pigmentation across the nose associated with a grove or ridge, referred to as transverse nasal groove or nasal crease. The crease has been particularly emphasized in the case of the allergic salute.[43,44]

Skin Color Contrasts of the Face

Thanks to the analysis of color contrasts between the different facial areas (forehead, cheek, chin and dark

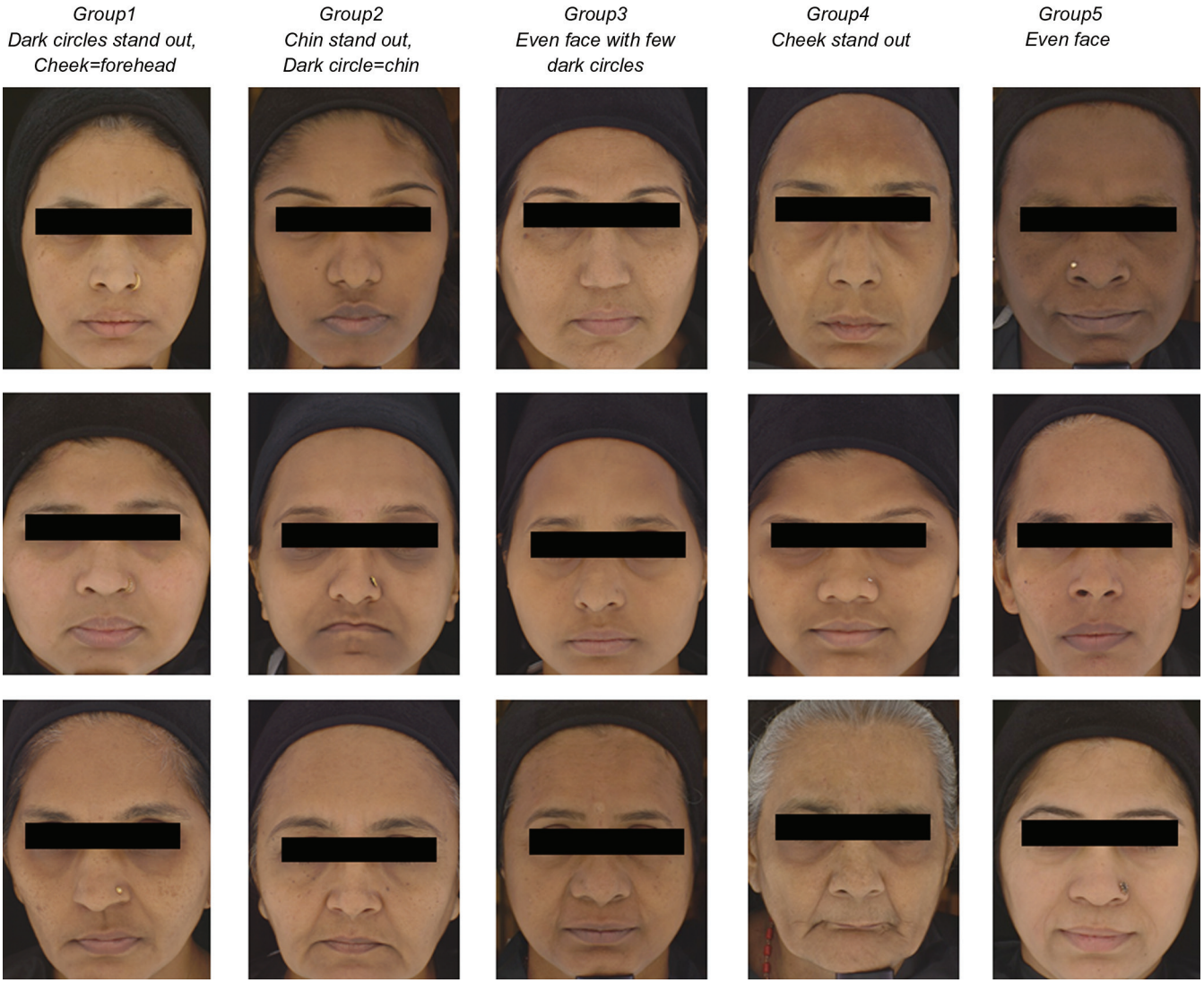

Figure 22: Facial skin color types based on the analysis of skin color contrasts

circles), five clusters (Fig. 22) were identified to illustrate the unevenness of the Indian women face. Dark circles play a big part in the segmentation due to their high frequence in India.

The cheek can be very light as compared to the rest of face leaving the forehead very dark comparatively (Group 4) or the chin can stand out by its darkness and lack of vividness (Group 2).

This again illustrates the importance of skin color heterogeneity in India with a wide diversity of skin color contrasts existing between the different parts of the face.

CONCLUSION

The color of the human skin results from complex mechanisms involving different genes, mainly related to melanin biosynthetic pathway. With its different flows of migration, India presents a wide range of biological diversity. This chapter highlights the uniqueness of Indian skin with its large diversity of color skin tone covering a color scale from very dark to light. According to this parameter, the country could be split diagonally from South West to North East, with the darker skin in the South and East. Globally skin complexion appears

not strongly affected by age compared to other Asian countries with a slight darkening of skin color with age particularly in the Southern region.

Skin color heterogeneity appears as a hallmark of Indian skin with an increase in facial skin color unevenness with age. This heterogeneity can be explained by an increase in pigmentary disorders, i.e. hyperpigmented spots and spread macules. These disorders occur at early stages and increase with age, contributing to overall facial unevenness. Indian facial skin also presents some original hyperpigmented areas, such as lip corners, marionette lines and nose bridges. In India, dark circles are the most prevalent hyperpigmented areas, darkening with age. This data raises the needs to further characterize and explore the mechanisms underlying the early onset and high prevalence of hyperpigmented spots, dyspigmented spread macules, and specific pigmented lines observed in the studied population.

These features are obviously of high concern for dermatological and cosmetological perspectives.

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