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Decoding skin oiliness and morphological characteristics in different skin phototypes in Brazil: an inclusive clinical study

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ABSTRACT

This study aimed to characterize the skin of Brazilian women with a range of skin phototypes who self-identified as having oily skin. To this end, 54 women aged 18-35, Fitzpatrick skin phototypes II to VI, were divided into 2 groups: Group A (phototypes II-III) and Group B (phototypes IV-VI). Sebum casual level, sebum excretion rate, sebaceous gland activity, shininess, skin barrier function, stratum corneum water content, skin pores and microrelief were evaluated. In addition, skin layers thickness and skin morphological characteristics were analyzed by Reflectance Confocal Microscopy. While sebum levels and excretion rates showed no significant difference between groups, Group B exhibited a significantly higher rate of sebum secretion within the infundibulum, a higher number of pores alongside higher skin roughness and increased desquamation. In addition, Group B presented a less homogeneous distribution of hyperpigmentation in the viable epidermis and greater dermal papillae depth compared to Group A. However, phototypes II and III showed higher interkeratinocyte reflectance in the stratum granulosum and higher granulosum layer thickness than darker phototypes, which suggests an improved epidermal hydration. These findings highlight the importance of considering skin color-specific variations in skin properties when developing cosmetics to meet the diverse needs of Brazilian consumers.

1. Introduction

Brazilian skin is remarkably diverse, reflecting the extensive history of miscegenation in the country. This unique mix of ethnicities has resulted in a wide spectrum of skin tones and types, each with specific characteristics and needs. A common characteristic of Brazilian skin is its tendency for oiliness [1, 2]. Understanding the heterogeneity of the consumers is essential for the creation of inclusive and effective cosmetic formulations that meet the unique needs of the Brazilian population.

Despite many similarities, there are notable differences between lighter and darker skin tones [3], which represents an opportunity for cosmetic and dermatological product companies to address the needs of ethnic diversity. In addition, skin response to sun exposure is highly dependent on color diversity [4].

Thus, understanding the structural and morphological differences between lighter and darker skin tones will provide relevant information into skin alterations such as hyperpigmentation, dry skin and scaliness [5].

In this context, the advanced biophysical and skin imaging techniques has been widely applied to evaluate the skin characteristics and in knowledge clinical studies. Skin is influenced by factors such as age, gender, skin type and history of sun exposure. Skin imaging techniques can assess parameters such as epidermal and dermal thickness, the amount and distribution of melanin, hydration, and skin microrelief, while being objective, in a non-invasive way, and real-time [6, 7]

The integration of these techniques allows for a more precise evaluation of the diverse skin phototypes, thereby facilitating the understanding of the attributes associated with each skin color. This can support and provide a foundation for the development of more effective and personalized skin care products that consider the physiology of each phototype, with particular attention to darker skin tones. Thus, the objective of this study was to characterize the skin of Brazilian women with various skin phototypes who self-reported as having oily skin.

2. Materials and methods

2.1. Study Design

After approval by the Ethics Committee of the School of Pharmaceutical Sciences of Ribeirão Preto, University of São Paulo (CEP/FCFRP; CAAE: 72958223.7.0000.5403), this study was carried out with 54 Brazilian women, aged 18-35 years, Fitzpatrick skin phototypes II to VI, who self-identified as having oily skin and presented sebum levels of $\geq 120 \mu\text{g}/\text{cm}^2$.

A screening test was performed on 90 women to assess the sebum content in the frontal area. From this initial group, 54 participants with sebum levels $\geq 120 \mu\text{g}/\text{cm}^2$ who met the inclusion/exclusion criteria were enrolled for the study.

Inclusion criteria were aged 18-35 years, healthy female, Fitzpatrick skin phototype II to VI and self-reporting oily skin. Some subjects had a history of acne or active acne. Exclusion criteria included: pregnancy or lactation; a history of adverse reactions to cosmetic products; use of medications that may cause an abnormal skin response; and localized or generalized dermatologic disease. Participants provided consent by signing an Informed Consent Form (ICF) that detailed all necessary study information.

The participants were divided into 2 groups. Group A: phototypes II and III and Group B: phototypes IV, V and VI. In addition, participants were instructed to adhere to the following specific procedures: wash their hair 24 hours before the study; refrain from applying any cosmetic products after showering the night before the study; not wash their faces the morning of the study; and bring their primary skin care and cleansing products on the day of the study for documentation by the investigator. Furthermore, participants were asked to refrain from consuming food or drink 20 minutes before assessments.

After a 30-minute period of acclimatization period in an air-conditioned room (20-22°C and 45-55% relative humidity), facial skin assessments were carried out.

The facial skin was analyzed in terms of sebum casual level, sebum excretion rate, sebaceous gland activity, shine, skin barrier function, hydration, skin pores and microrelief. Reflectance confocal microscopy (RCM) was applied to analyzed skin layer thickness and skin morphologic characteristics. All measurements were taken in triplicate on the frontal and/or malar regions of the face.

2.1.1. Determination of sebum amount in the skin

The Sebumeter SM815 photometric device (Courage & Khazaka Electronic, Germany) was used to determine the sebum content on the skin surface. This involved applying a special opaque tape to the skin with light pressure for 30 seconds to collect the sebum. The transparency of the tape was then measured, with the result values representing the amount of sebum present on the skin.

Six Casual Level measurements were taken on the frontal area of the face (two side-by-side measurements in each area: right, central, and left), as illustrated in Figure 1. Following the measurements, the skin was subjected to a standardized degreasing procedure as described below. One-hour later, new measurements were taken in the same areas to determine the Sebum Excretion Rate (SER).

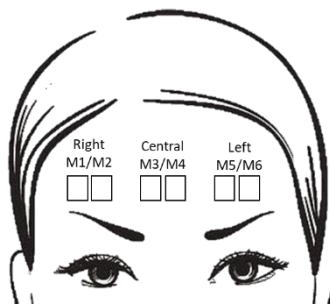


Figure 1. Regions where sebum measurements were performed. M1 and M2: right frontal region; M3 and M4: middle frontal region; M5 and M6: left frontal region.

The degreasing procedure consisted of the application of cotton pads saturated with 1.5mL of 70% ethanol. One side of the cotton pad was used to clean the forehead, then the pad was replaced, and the area was cleaned again in the opposite direction using a fresh, ethanol-saturated pad. This process was repeated five times to ensure optimal decreasing.

Subsequently, study participants were asked to remain at rest for 1 hour (+10 minutes max.) in a comfortable, seated position under the same controlled environmental conditions (20-22°C and 45-55% relative humidity). During this rest period, the subjects were instructed to refrain from touching their faces.

2.1.2. Evaluation of active sebaceous glands

Sebufix® F16 (Courage & Khazaka Electronic, Germany) is a specialized film designed to be applied to the skin surface for 30 seconds and to absorb sebum and create transparent spots [1]. When attached to the Visioscan® camera (Courage & Khazaka Electronic, Germany), the Sebufix® F16 enables real-time, exclusive monitoring of the sebum production quantity. Upon application of the film to the skin, sebum becomes visible within seconds as transparent spots, the size of which corresponds to the amount of sebum present. The lateral spread of sebum on the film was minimized. Skin with low sebum content appears as a few, small spots, whereas oily skin presents with a large number of large spots. Image analysis was performed by placing the film in the Visioscan device to determine the number and size of the spots, providing a quantitative measurement of sebaceous gland activity. A Sebufix measurement was performed in the area between M2 and M3 zones one hour after the skin degreasing procedure.

2.1.3. Determination of the stratum corneum water content

The Corneometer® CM 825 device (Courage & Khazaka Electronic, Germany) was used to assess the hydration level of the stratum corneum in the malar area (randomized). This device operates on the principle of electrical capacitance. Results were expressed in arbitrary units (A.U.) [2].

2.1.4. Determination of transepidermal water loss (TEWL)

The Tewameter®™ devices (Courage & Khazaka Electronic, Germany) were used to assess the barrier function of the skin in the malar area (randomized). The function of these devices is to measure the rate of transepidermal water loss based on the diffusion principle described by Adolf Fick. The values obtained are expressed in g/h/m² [6].

2.1.5. Analysis of skin characteristics using high-resolution images

The VisioFace® RD (Courage & Khazaka Electronic, Germany) has a high-resolution camera housed within a cabin that enables a high-resolution facial photograph under white light. The image analysis is performed with a software that allows the quantification of fine and large

pores, as well as their areas, and identifies spots and wrinkles [8, 9]. For this test, the quantification of large pores was carried out in the frontal and malar regions. Subsequently, the values were categorized into scores according to the standard count by Leite and Maia Campos (2020) [1] (Table 1). Finally, the values were converted into relative frequencies and presented graphically.

Table 1. Classification of pore quantity [1].

Pores count/Score	1	2	3	4	5
Count Large	0 to 5	6 to 10	11 to 85	86 to 152	Above 153

2.1.6. Determination of skin microrelief

The Visioscan® VC 20 plus (Courage & Khazaka Electronic, Germany), a P&B video camera system with UV-A illumination, was utilized to determine skin microrelief. This device uses the SELS (*Surface Evaluation of the Living Skin*) image analysis software, which provides qualitative and quantitative information about the skin surface under physiological conditions. Optical profilometry techniques were applied using an image digitization process obtained by a video camera [10, 11, 12]. Measurements were performed in a randomized manner on the malar area. For this study, the Skin roughness and Skin scaliness were evaluated using the SEr and SEsc parameters. The first one quantifies the proportion of gray levels exceeding a predefined threshold relative to the entire image. A lower SEr value corresponds to a rougher skin surface. The second one represents the proportion of pixels exceeding a predefined gray-level threshold relative to the total number of pixels in the image. A lower SEsc value corresponds to reduced skin scaliness, indicating a lower degree of stratum corneum desquamation.

2.1.7. Evaluation of the morphological characteristics of the skin

The cellular characteristics of the different layers of the epidermis were assessed using the Vivascope® 1500 reflectance confocal microscope (RCM), which features an 830 nm laser source and an immersion objective capable of capturing 20 frames per second. Microscopic images were obtained from the Vivastack imaging system, which provides multiple confocal images at successive depths at a given location in the tissue in a standardized manner. The following

parameters were analyzed from the images obtained: thickness of the different layers of the epidermis, organization of the keratinocytes, brightness of the stratum corneum and granular layers, pigmentation patterns and shape of the contours of the dermal papillae [10, 11, 12, 13, 14]. Measurements were performed on the malar region of the face. For subjects with acne-related post-inflammatory dark spots on the malar area, measurements focused on both the hyperpigmented and non-hyperpigmented areas.

2.1.8. Skin Shininess Analysis

Shininess was assessed with the Lightcam® device from Newton Technologies (Lyon, France). Cross-polarized and parallel light photographs were taken in the frontal area with a camera in an area of 2.5x2 cm². Software analysis provides the following parameters:

Gs: Gloss contrast;

Gc: Specular Brightness;

Sr: % of the reflected surface – number of bright pixels in the image.

Parameters and images are stored directly in the software database.

Two Lightcam® measurements were taken in the frontal area without touching the skin of the face: one on the right and one on the left. The images were used for quantification of shine using the Gc parameter (Contrast Gloss). This parameter is used for moderately glossy surfaces, such as the skin, in which the light source is not visible.

2.2. Statistical analysis

The experimental data were processed and analyzed using GraphPad Prism® version 8.4.3 (GraphPad Software San Diego, CA, USA) and Origin® 9.75 (OriginLab Corporation, Northampton, MA, USA). The t-test was employed for parametric analysis, and the Mann-Whitney U test was used for non-parametric analysis.

3. Results

The study population comprised 54 women divided into two groups, as described in Table 2.

Table 2. Demography of studied population.

		Group A	Group B
Age	Mean	24	24
	Range	18-32	18–35
Phototypes		II: 15	IV: 10
		III: 12	V: 10
			VI: 7

There were no statistically significant differences between the groups regarding surface sebum casual level (before skin degreasing) and sebum excretion rate (SER) (one hour after skin degreasing). However, Group B presented a significantly higher ($p<0.05$) gradient (%/s) of sebum in the infundibulum (Figure 2).

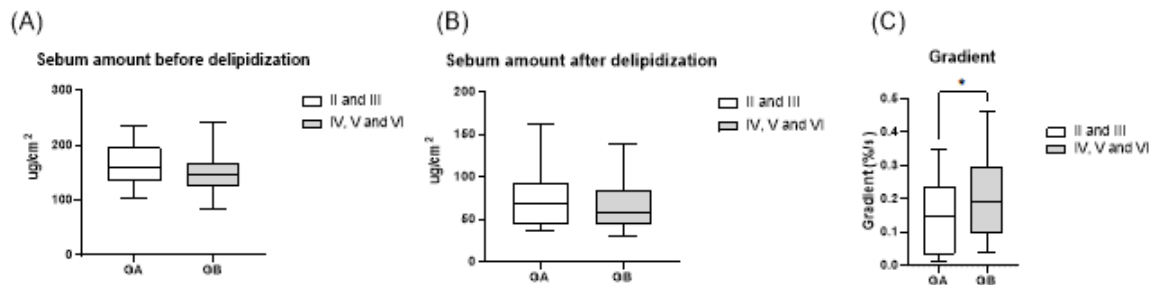


Figure 2. (A) Sebum amount before skin degreasing (casual level) (B) Sebum amount 1 hour after skin degreasing (excretion rate) (C) Gradient (%/s) of the sebum in the infundibulum measured by Sebufix

*Significant difference between Group A (GA) and Group B (GB) ($p<0.05$).

No significant differences in transepidermal water loss (TEWL) were observed between the two groups. However, stratum corneum water content differed significantly ($p<0.05$), with Group B exhibiting higher values than Group A (Figure 3). Analysis of skin shininess, as shown by Figure 4, revealed a higher Gc parameter, and thus greater brightness, in Group A.

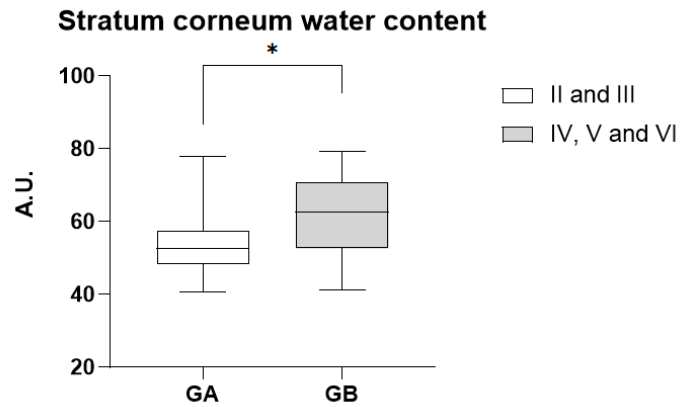


Figure 3. Stratum corneum water content (A.U) measured by Corneometer. *Significant difference between Group A (GA) and Group B (GB) ($p < 0.05$)

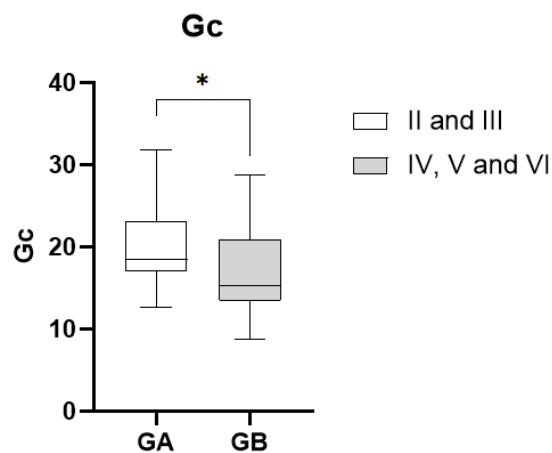


Figure 4. Specular brightness (Gc) evaluated parameter in the skin shininess analysis. *Significant difference between Group A (GA) and Group B (GB) ($p < 0.05$)

Analysis of skin microrelief revealed significant differences between the groups. Group B showed significantly lower values ($p < 0.05$) for SEr (roughness) and higher values for SESc (scaliness) indicating higher overall roughness and higher skin desquamation compared to Group A (Figures 5 and 6).

Furthermore, Group B showed a higher count of large pores (Figure 7).

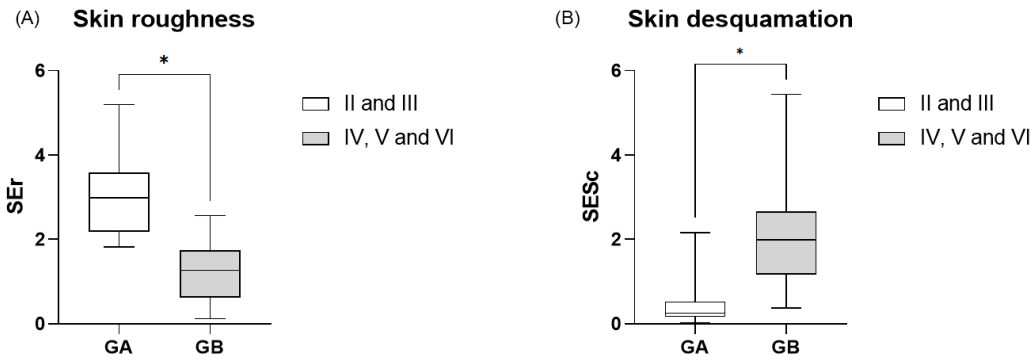


Figure 5. Skin microrelief parameters: (A) Ser (roughness) and (B) SESC (desquamation) in the Groups A (GA) and B (GB). *Significant difference between Group A (GA) and Group B (GB) ($p < 0.05$).

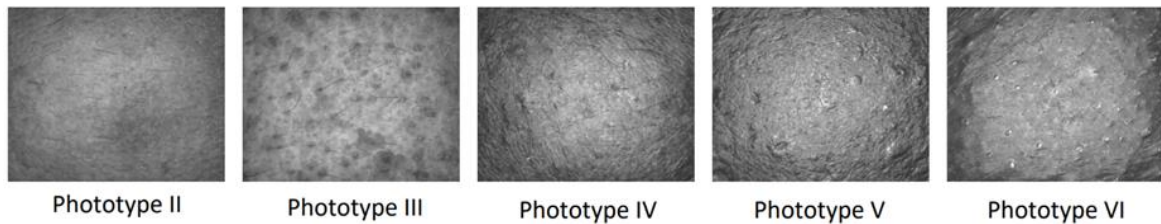


Figure 6. Representative images of skin microrelief across different skin phototypes. Skin phototypes II and III are part of Group A (GA) and Phototype IV, V and VI are part of Group B (GB), which higher roughness and skin scaliness are observed.

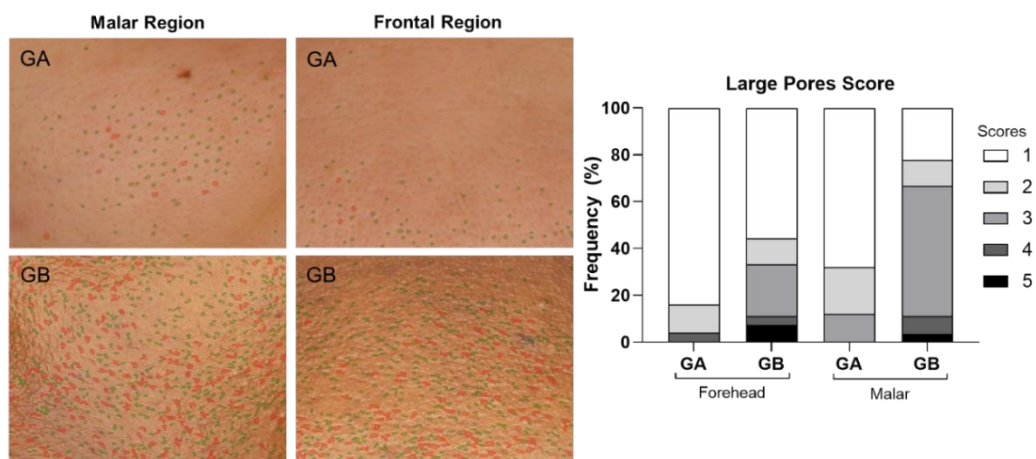


Figure 7. Representative images of pores count in malar and frontal region for Groups A (GA and B (GB); Large Pores Scores (red ones) by frequency (%) of GA and GB for malar and frontal region.

Reflectance confocal microscopy image analysis showed that while both groups presented similar stratum corneum thickness, Group A displayed a significant thicker stratum granulosum

compared to Group B ($p<0.05$). On the other hand, Group B demonstrated a significantly greater dermal papillae depth ($p<0.05$) (Figure 8).

Morphological analysis of RCM images, using a standardized scoring system, indicated significantly greater brightness in the basal layer of Group B ($p<0.05$). In contrast, Group A received more favorable scores for furrow morphology (Figures 9 and 10) ($p<0.05$).

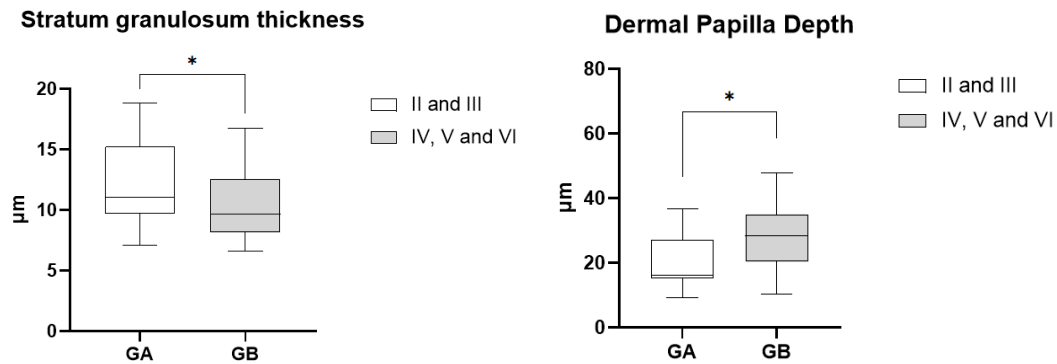


Figure 8. Stratum granulosum thickness and dermal papilla depth evaluated by reflectance confocal microscopy in Group A (GA) and Group B (GB)

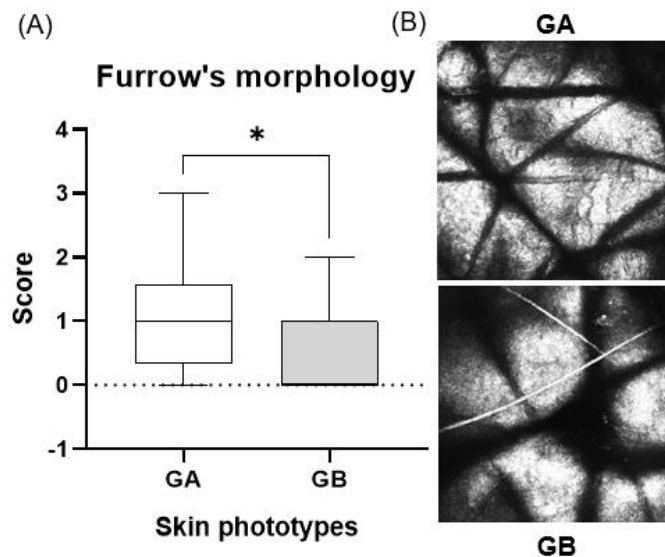


Figure 9. (A) Furrow's morphology comparison between Group A – lighter phototypes (GA) and Group B – darker phototypes (GB); (B) Reflectance confocal microscopy representative images showing Furrows morphology of Group A (GA) and Group B (GB) *Significant difference between Group A (GA) and Group B (GB) ($p<0.05$).

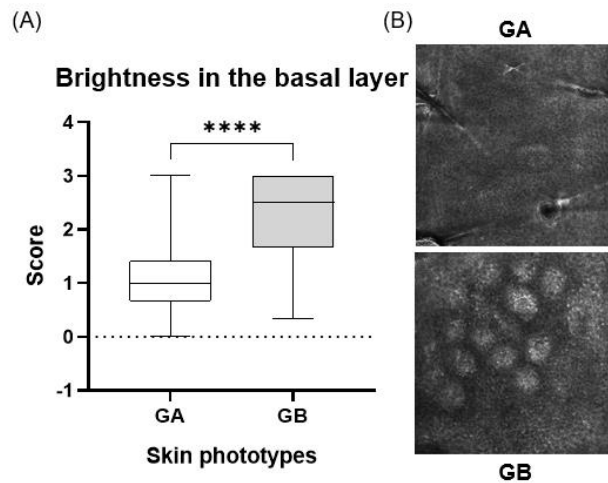


Figure 10. (A) Brightness in the basal layer in Group A (GA) and Group B (GB); (B) Reflectance confocal microscopy representative images showing the basal layer of Group A (GA) and Group B (GB) *Significant difference between Group A (GA) and Group B (GB) ($p < 0.05$).

In addition, post-inflammatory hyperpigmentation (PIH) acne-related spots were observed in darker phototypes, particularly in phototype IV. Figure 11 illustrates the morphological alterations of the dermal papillae at the dermal-epidermal junction (DEJ) associated with this observation.

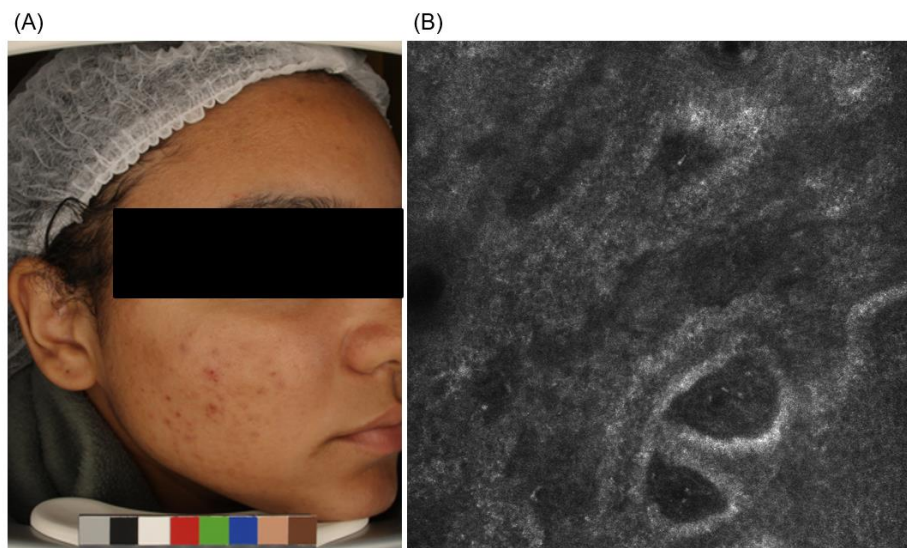


Figure 11. (A); Representative high-resolution image and (B); reflectance confocal microscopy images showing the post-inflammatory hyperpigmentation in the study participants - phototype IV.

4. Discussion

This study provides valuable insights into the characterization of oily skin across a diverse range of skin color of Brazilian women. While surface sebum levels were comparable across phototypes II – VI, key differences emerged in sebaceous gland activity, skin hydration, skin microrelief, skin pores and epidermal morphology. Specifically, darker phototypes demonstrated a higher sebum gradient within the infundibulum and a higher frequency of number of large pores, suggesting elevated sebaceous gland activity that may not be reflected in surface measurements alone.

Despite comparable surface sebum levels, lighter phototypes (II-III) exhibited higher skin shininess while darker phototypes showed higher skin hydration levels.

The skin texture analysis showed rougher and scallier skin in the darker phototypes group, suggesting higher desquamation rate [15] compared to lighter phototypes.

Despite similar stratum corneum and total epidermis thickness across groups, morphological and structural analysis showed some unique characteristics. Notably, darker phototypes had a significantly higher dermal papillae depth which increased proportionally with the phototype [16]. However, lighter phototypes presented a thicker stratum granulosum, suggesting a higher level of hydration within this epidermal layer [17].

Reflectance Confocal Microscopy (RCM) further corroborated the increased roughness and desquamation observed in darker phototypes, revealing alterations in furrows morphology and stratum corneum surface irregularities. Furthermore, the greater basal layer brightness and morphological alterations in the DEJ, such as irregular shape and size of dermal papillae, observed in RCM image analysis, is consistent with post-inflammatory hyperpigmentation, particularly in phototype IV individuals, further emphasizes the susceptibility of darker skin to pigmentary changes [9].

This pilot study represents a comprehensive approach combining biophysical and imaging techniques across a wide spectrum of Fitzpatrick skin types, contributing to an initial understanding of oily skin in a diverse skin color population in Brazil.

Future research will expand the sample size within each phototype group and integrate biological samples analysis, including sebum and stratum corneum lipidomic, to further elucidate the biochemical aspects of skin oiliness across different skin tones.

5. Conclusion

While measurements of surface sebum levels showed no significant differences between phototypes, other differences appeared in other aspects of oily skin. Darker phototypes had a higher sebum gradient within the infundibulum, a greater frequency of large pores, as well as rougher and scalier skin texture compared to lighter phototypes. In addition, different skin morphological characteristics were observed, with lighter phototypes showing a thicker stratum granulosum layer and darker phototypes exhibiting a deeper dermal papilla, alongside signs of hyperpigmentation in the basal layer and dermal-epidermal junction.

Considering these results, our findings highlight the importance of skin knowledge studies to guide the research and development of personalized skin care products for the diverse needs of the Brazilian consumers with oily skin.

6. Conflict of Interest Statement

None.

7. References

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