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# *“Wettability, a reliable method to measure the surface energy of the cosmetic products”*

**Ferial Fanian * [1], Sophie Mac[2], Shannel Curic[1], Rania Bakour[1], Philippe Humbert [3]**

[1] Scientific, FILLMED Laboratories, Paris ; [2] CEO, Skinexigence, Besançon; [3] Scientific, CERT, Ornans, France

## 1. Introduction

The stratum corneum, as the outermost layer of the epidermis, serves as the primary barrier between the body and its external environment. Its structure — a dense arrangement of corneocytes embedded in a lipid matrix — is finely tuned to limit transepidermal water loss (TEWL) while maintaining the skin's hydration balance [1,2]. This hydration is not only essential for barrier integrity, but also influences the mechanical properties and biochemical activity of the skin surface [3]. A well-hydrated stratum corneum supports enzymatic processes, improves elasticity, and enhances overall skin appearance. In contrast, dehydration is often associated with barrier dysfunction, roughness, and increased susceptibility to irritants [4].

From a surface science perspective, the skin’s hydration state directly impacts its wettability and hydrophilic/hydrophobic balance. When hydrated, the stratum corneum becomes more hydrophilic, facilitating the spread and absorption of water-based topical formulations [5]. Conversely, a dry or lipid-enriched surface tends to exhibit higher hydrophobicity, which can hinder product penetration and alter the sensory profile of a cosmetic application [6]. Evaluating these surface properties through contact angle measurements has become a valuable technique in both dermatological research and cosmetic formulation, offering a non-invasive and quantifiable way to understand how products interact with skin under various physiological conditions [7,8].

Several instrumental methods have been developed to assess skin hydration and evaluate the condition of the stratum corneum. Among the most widely adopted is the corneometer, which quantifies skin moisture by detecting variations in the dielectric constant of the superficial layers [9]. Other non-invasive techniques such as confocal Raman spectroscopy, impedance spectroscopy, and TEWL provide complementary data on water content and barrier integrity [10,11]. However, these methods tend to focus primarily on the bulk hydration state of the stratum corneum rather than the surface interaction properties relevant to topical applications. In this context, wettability measurements based on contact angle analysis have emerged as a promising approach to evaluate the surface energy and functional state of the skin.

Wettability reflects the ability of a liquid to spread over a solid surface, and in skin science, it serves as a useful indicator of surface condition, treatment efficacy, and formulation compatibility. It is typically expressed through the contact angle (teta θ), which is the angle formed at the liquid–solid–air interface when a drop is deposited on a surface (Figure 1). This angle provides a direct measure of the balance between adhesive forces (liquid-skin interaction) and cohesive forces (within the liquid itself) [5,6]. A low contact angle (< 90°) reflects a hydrophilic surface — often associated with a hydrated or cleansed skin — whereas a high contact angle (> 90°) indicates hydrophobic behavior, typically linked to dryness, lipid enrichment, or surface contamination.

In skin-related studies, the sessile drop technique is the most common method for determining the contact angle. A microliter droplet of a test liquid (often water, diiodomethane, or formamide) is deposited onto the skin or a biomimetic surface, and the angle is measured using a high-resolution camera and goniometer [8]. Some advanced systems also allow for dynamic contact angle analysis, measuring both advancing and receding angles to assess hysteresis and better characterize surface heterogeneity or roughness. These measurements can be performed in vitro on skin models or reconstructed epidermis, as well as in vivo directly on human skin, making them highly versatile for cosmetic and dermatological research [12,13].

The application of wettability measurements in dermocosmetic research has gained increasing relevance, particularly in the context of product development and skin compatibility assessment. By providing objective, quantitative data on how cosmetic formulations interact with the skin surface, contact angle analysis supports a more rational approach to formulation design. Beyond formulation devellopement, wettability analysis is valuable in the screening of active ingredients, allowing researchers to compare their effects on skin surface properties, including hydration and lipid modulation.

The method is also used to monitor treatment efficacy both in vitro, using reconstructed skin models, and in vivo on human subjects, offering a non-invasive alternative to more invasive or bulk-sensitive techniques. Furthermore, changes in wettability can serve as indicators of skin barrier status, allowing researchers to detect alterations due to topical treatments, aging, or environmental stress. Finally, the data obtained can be used to substantiate product claims, such as enhanced hydration, improved spreadability, or restored skin balance, adding scientific credibility to marketing narratives. Overall, wettability measurements offer a versatile and reproducible tool for both fundamental research and applied cosmetic science.

The aim of this article was to highlight the advantages of wettability measurements in the field of dermocosmetic. In addition, the reliability of this method has been confirmed in a preliminary study evaluating the efficacy of two different moisturizing cosmetic products.

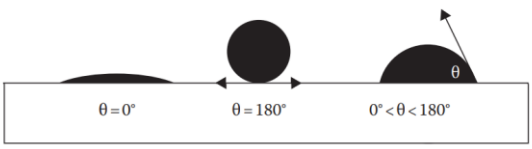



**Figure 1:** Wettability is expressed through the contact angle (θ), which is the angle formed at the liquid–solid–air interface when a drop is deposited on a surface. A low contact angle (< 90°) signifies a hydrophilic surface — whereas a high contact angle (> 90°) indicates hydrophobic behavior.

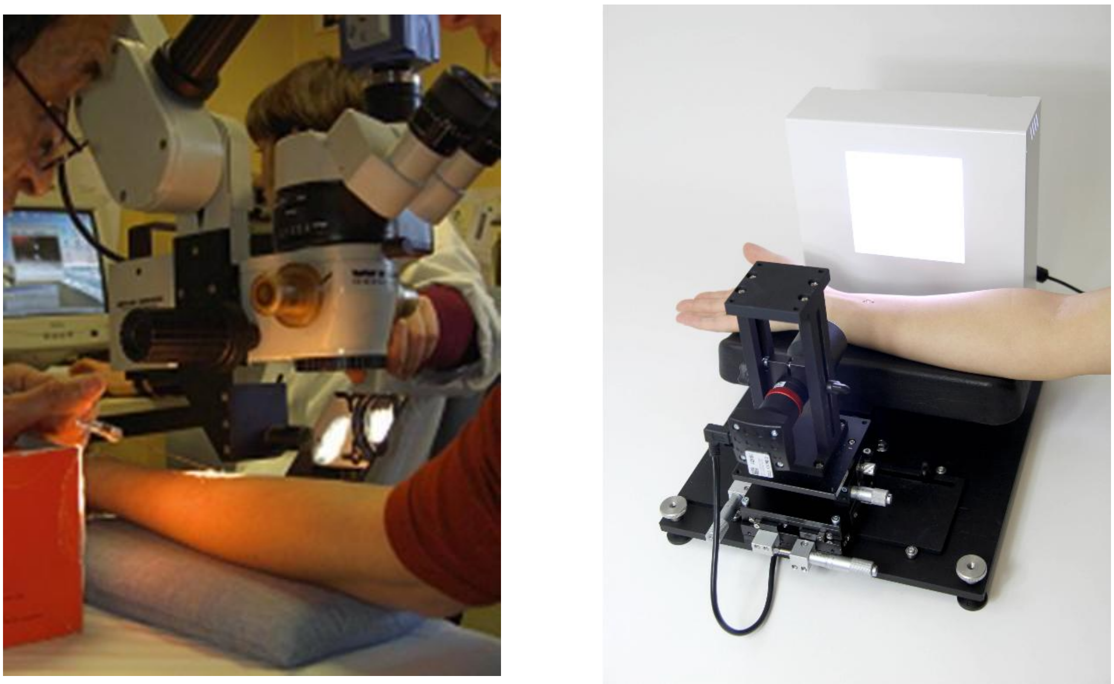
## 2. Technology

For decades, several researchers have investigated skin wettability using different methods and tools to measure contact angle, both in vitro and in vivo. In 2018, Huhtamäki et al. detailed procedures for sessile drop, captive bubble, and tilting plate methods, including guidelines on droplet volume, environmental control, and data analysis for measuring advancing and receding angles [8].

However, among these studies, Elkhyat et al. have pioneered in vivo methodologies to assess skin hydrophobicity and wettability with a high degree of physiological relevance and precision. In 2001, Elkhyat et al. introduced a novel in vivo approach to quantify the hydrophobicity of human skin by measuring contact angles directly on the skin surface. They proposed new parameters, such as the hydrophilia index (Hi) and hydrophobia index (Ho), to classify skin surfaces based on their affinity to water. This work laid the foundation for subsequent research into skin surface properties and their implications in dermatology and cosmetology [12]. Elkhyat's technique is based on a manual goniometric system designed specifically for in vivo measurement of the contact angle on human skin [12, 14]. A microliter glass syringe or micropipette was used to precisely deposit a 2–5 µL droplet of test liquid (usually distilled water, formamide, or diiodomethane) directly onto the forearm or other target area of the skin. The droplet was placed gently to avoid deformation or splashing. The droplet profile was recorded immediately after deposition using a video camera (CDD-Iris, Sony, France) connected to a computer and mounted on a microscope (Wild Heerbrugg M650, Switzerland), with a magnifi cation of x16, fitted with a slanted mirror. (Figure 2a). Contact angles were determined from the images using custom-developed image analysis software or manual angle tools, typically by drawing tangents at the liquid–solid–air interface. Elkhyat also introduced a hydrophobicity index, derived from the difference in contact angles between polar and nonpolar liquids, which served as a composite marker of skin surface properties. His protocol allows measurement before and after treatments, sebum removal, or hydration, providing a sensitive tool for evaluating physiological changes [15].

Based on the same principle, The Drop Angle Meter (DAM) by Courage + Khazaka Electronic GmbH is a commercially available device that automates the measurement of contact angles on skin and other substrates [16] (Figure 2b). It consists of a motorized dosing unit for accurate and reproducible droplet delivery, a high-resolution digital camera, and proprietary analysis software. The system is designed to measure both static and dynamic contact angles, including advancing and receding angles, enabling more complete surface energy profiling. The test is typically performed using standardized liquids, and the droplet volume (usually 3–5 µL) is precisely controlled. The camera captures side images of the droplet immediately upon deposition, and the software computes the contact angle using mathematical curve fitting. The device includes accessories to stabilize in vivo skin measurements and a temperature-controlled sample stage for in vitro use. Surface energy can be calculated automatically using models such as Owens–Wendt, offering high reproducibility and user-friendliness for both research and industrial use [5, 8].

Both Elkhyat's technique and the DAM rely on the sessile drop method, but they differ significantly in setup, purpose, and flexibility. Elkhyat's system is manually operated, customizable, and highly adaptable to different skin conditions, body areas, and liquids. It is well-suited for exploratory, mechanistic research in academic settings. However, it is more sensitive to operator variability and requires manual image processing and training. In contrast, the DAM provides a standardized, automated workflow, minimizing user bias and improving data reproducibility. Its integration of software for dynamic angle analysis and surface energy calculation makes it highly effective in routine testing, claim substantiation, and high-throughput environments. While Elkhyat's method allows deeper physiological insight, the DAM excels in usability and consistency, making both methods complementary depending on the study's objectives.



**a)** **b)**

**Figure 2.** Two devices used in the literature to measure skin wettability.
a) The prototype developed and used by Dr Elkhyat
b) Drop Angle Meter DM300 (from Courage + Khazaka)

## 3. Clinical data

3.1. Wettability measurment by prototype microscope

Elkhyat's prototype was used in different studies and showed its sensitivity to quantify the variation of wettability according to body location [15]. The volar forearm, due to its poor amount of sebum is semi hydrophobic contact angle (θw = 80°-91°). On the opposite, on the forehead, rich in sebum, water spreads over (θw = 57°-73°) which corresponds to a hydrophilic surface. The in vivo evaluation of the nails shows that human nail is a hydrophilic surface with a θw = 65°. Such regional differences must be considered when interpreting treatment efficacy, particularly in multi-site studies.

The difference between ethnicity was also observed. In a study, it has been demonstrated that the forehead skin wettability is significantly different between Black people (Africans or Caribbeans) (θw = 71°) and Mixed races (African or Caribbean) (θw = 67°) and Caucasians (θw = 67°) ($p < 0.05$) [17].

In addition, this technique was also able to show that the water contact angle θw on the forehead of 60 children (aged 7–11), and the results showed a θw = 87°, higher than adults indicating the skin is more hydrophobic than adults. Note that the sebum level measured on these children was particularly low (17 µg/cm2) [18].

Degreasing with organic solvents or washing with soap and water increases considerably the skin hydrophobia. This effect was observed by increasing the water contact angle by 10 to 15° [19]. The initial skin hydrophilia of the forehead was recovered 2 h later after degreasing, time required for the reconstitution of the sebum current level. The degreasing of the nails with organic solvents also increases its hydrophobia, increasing the contact angle by 25° [20].

On the other hand, applying a moisturizer on the face of 60children for 1week showed a significant decrease in contact angle by 10° indicating an increase in skin hydration (+15 arbitrary unit) [18]. Another cosmetical application was the quantification of spray application of thermal water on the hydrophobic tendency of dry skin [21]. In this study, the wettabilty measurment showed that thermal water reduced the skin hydrophobia by reducing the contact angle by 10°.This effect disappeared 30 min after application.

3.2. Drop Angle Meter® (DAM)

This technique being recent, the publication using it are limited. However, we performed a pilot short term study on 13 subjects from 19 to 68 years old to assess two different formulations (HAB5 and HAB3) on skin wettability and hydration level (HI) measured by DAM and corneometry. The evaluation consisted on short term effects e(Day0 = baseline, Day0+2 hrs post application and Day0+6 hrs after application) and mid-term effects after 3 and 6 days of twice application per day. In the group treated with HAB5 (HA + Provitamin B5), the contact angle decreased significantly by 53%, 46%, 15% and 12% after respectively 2h, 6h, 3 days and 7 days compared to baseline, indicating a short term and mid-term moisturizing effect of HAB5. This was correlated by a significant increase of the HI by 38%, 27%, 28% and 34% respectively(Figure 3-4). On the contrary, in the untreated area group, the contact angle and HI remained stable at each timepoint.

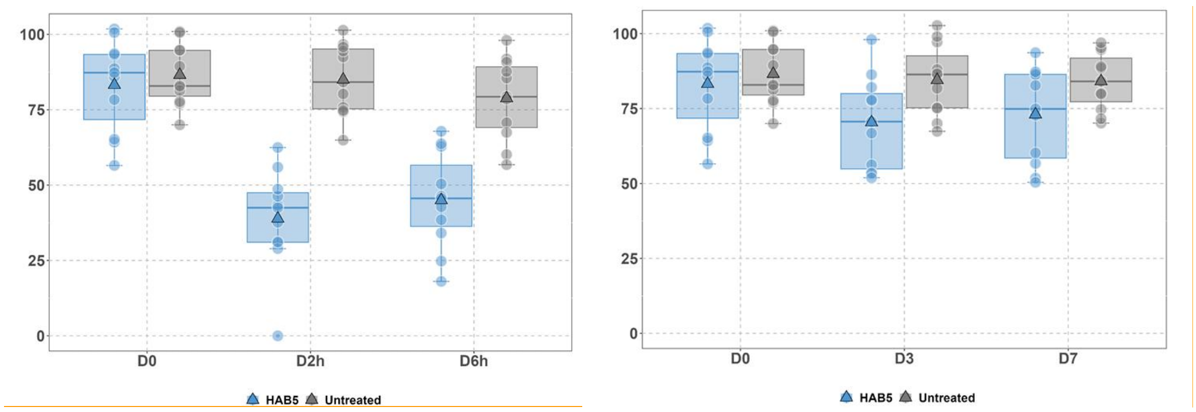



**Figure 3:** Evolution of the Contact Angle during the trial after the application of the product HAB5 (left = short term and right=mid-term)

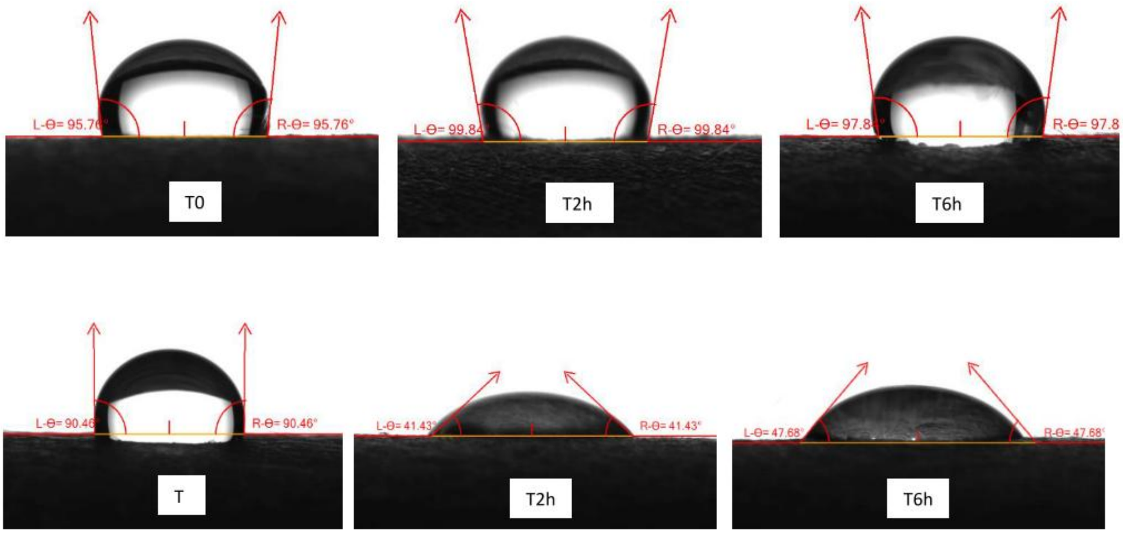



**Figure 4:** Examples of contact angle measurements on forearms of two subjects with Drop Angle Meter DM300 (from Courage + Khazaka).
Top: untreated area, bottom: area treated with HAB5

In the group treated with HAB3 (HA + Vitamin B3), the contact angle decreased significantly by 33% and 34%, after 2h and 6h and non-significantly by 9% and 5% after 3 days and 7 days compared to baseline, indicating a short term moisturizing effect of HAB3. This was correlated by a significant increase of the HI by 44%, 31%, 23% and 38% respectively (Figure 5). On the contrary, in the untreated area group, the contact angle and HI remained stable at each timepoint.

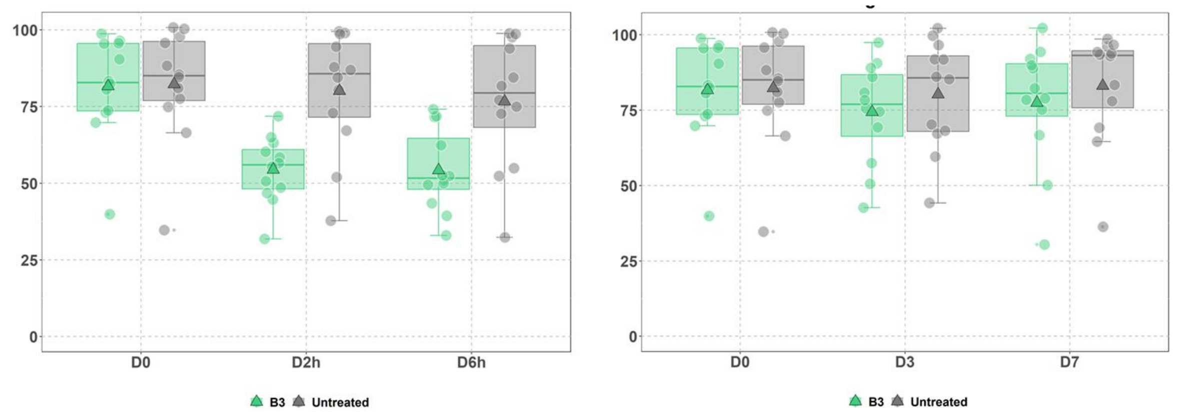



**Figure 5:** Evolution of the Contact Angle during the trial after the application of the product HAB3 (left = short term and right=mid-term)

## 4. Discussion

Skin wettability is a well-established parameter in dermatological and cosmetical research, recognized as a reliable method for assessing skin hydration and the effectiveness of moisturizing formulations. Several studies have validated its relevance both in vitro and in vivo.

Indeed, Capra et al. explored the correlation between in vitro and in vivo contact angle data using the sessile drop method on skin replicas and in vivo human forearm skin after application of various formulations [5]. Mavon et al. studied the impact of sebum and stratum corneum skin lipids on surface energy using polar and nonpolar probe liquids [6] and in 2000 they employed radiolabeled markers to measure contact angle and absorption rates of human skin samples hydrated to different levels and treated with sunscreens [22]. Krawczyk et al. published several articles describing different approaches. In 2012, contact angles of water, formamide, and diiodomethane were measured on forearm skin using sessile drop techniques, and analyzed via surface energy models [7]. Then, they used different surfactant solutions on the skin using goniometry, followed by surface energy calculations via Lifshitz–van der Waals theory [23] and Owens-Wendt method [24].

Kottner et al. analyzed the effect of anatomical variation of healthy individuals using standardized goniometry [13] or tribometer under controlled hydration conditions [25]. More recently, Moonen et al. employed artificial skin platforms to mimic wettability for biosensor testing. Artificial skin surfaces were fabricated and characterized using contact angle measurements with water and isopropanol, then compared to in vivo skin data [26].

In clinical research, wettability assessment extends far beyond the measurement of static contact angle. While the sessile drop method remains the most common approach, additional parameters such as dynamic contact angles (advancing and receding), contact angle hysteresis, spreading time, droplet absorption rate, and even droplet footprint are increasingly reported to provide a more comprehensive characterization of the skin surface. These parameters are particularly relevant in vivo, where physiological variability, sebum distribution, and regional hydration differences significantly influence measurements [13, 15]. For instance, the difference between advancing and receding angles — contact angle hysteresis — has been associated with both surface roughness and heterogeneous hydrolipidic film distribution, as demonstrated by Elkhyat et al. in studies comparing facial and forearm skin [14]. Additionally, the rate of droplet spreading or absorption has been correlated with stratum corneum hydration and permeability, providing indirect insight into barrier function [6]. In several clinical trials, these variables have been used to monitor the effects of topical formulations — such as hydrating serums or barrier creams — by showing measurable changes in wettability parameters within hours or days after application [5]. Moreover, coupling wettability data with Corneometer® measurements enhances the interpretation of skin hydration kinetics, as decreased contact angles often align with improved capacitance readings [9]. Overall, the integration of multiple wettability parameters in clinical trials offers a sensitive, non-invasive approach to assess treatment efficacy, surface physiology, and product performance in vivo.

Compared to conventional techniques such as TEWL and corneometry, which respectively assess the skin's barrier function and stratum corneum hydration, wettability measurements offer a complementary and surface-sensitive approach. While TEWL provides indirect information on epidermal integrity and corneometry quantifies water content based on dielectric properties, neither method captures the physicochemical behavior of the skin–product interface. In contrast, wettability analysis—through parameters such as static and dynamic contact angles, spreading kinetics, and surface free energy decomposition—enables the characterization of how the skin surface interacts with liquids. This is particularly relevant for evaluating the performance and sensorial properties of topical formulations. Furthermore, changes in wettability often appear earlier or more distinctly than shifts in TEWL or capacitance, making it a sensitive and non-invasive marker for detecting treatment-induced modifications at the skin surface (e.g., cleanin, sebum removal, moisturizing).

In this study, we confirmed the sensitivity and reliability of contact angle analysis and corneometry for evaluating the short-term and mid-term effects of moisturizing formulations.

Both tested formulations one containing hyaluronic acid and pro-vitamin B5, the other containing hyaluronic acid and niacinamide (Vitamin B3) significantly increased skin hydration and surface wettability after a single application, as shown by reduced contact angle values and elevated hydration index (HI) at 2h, 6h, 3 days and 7 days post-application. These effects were significantly different from the untreated areas.

The observed parallelism between contact angle reduction and HI increase reinforces the correlation between skin surface energy changes and stratum corneum hydration, supporting the use of both methods in complementary fashion. These findings support previous evidence and suggest that wettability analysis offers a robust, non-invasive tool for evaluating topical efficacy, particularly when combined with standard hydration metrics.

## 5. Conclusion

Wettability measurement is particularly valuable for its non-invasiveness, repeatability, and its ability to detect subtle physiological changes on the skin surface (sensitivity). It is a reliable, reproducible and validated method for evaluating skin surface energy and is well correlated with skin hydration levels assessed by corneometry. Especially, Drop Angle Meter DM300 (from Courage + Khazaka) is easy-to-use and suitable to perform immediate evaluation of the cosmetic product as well as for kinetic evaluation over time. The limitation of this machin is the zone to be tested. As forearm is a sebum free zone, a device which can measure this parameter on every single surface of the body is lacking. In addition, the behavior of the cosmetic products is different on the sebum-free and sebum-containing zones. Therefore, an update should be performed to the device design in order to be able to use the device everywhere on the body.

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