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Skin effect of facial cleansing combined with an electric sonic device

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Abstract

Background: New technologies, such as sonic devices, have been developed to optimize the skin cleansing process and improve its efficiency. To evaluate the effectiveness of these cosmetic procedures, skin bioengineering is an objective method to assess the biophysical parameters of the skin.

Aims: This study aimed to assess the effect of facial cleansing on the physiological properties of the skin by comparing a cleansing process with cosmetic product applied manually to cleansing with cosmetic product associated with the use of an electric sonic device.

Patients/Methods: A gentle skin cleanser was applied to the entire face of 12 subjects; the sonic device was used on one half of the face and the manual process was performed on the other half. Instrumental skin analyses included sebummetry, corneometry, transepidermal water loss (TEWL), infrared thermography, and high-frequency ultrasound and were measured before and up to 90 min after cleansing. Results were compared using two-way ANOVA and Friedman tests.

Results: Data obtained from the statistical analysis of sebummetry, TEWL, thermography, and ultrasound parameters did not show any significant difference. When assessing the corneometry parameters, a significant reduction in hydration values (17.19%) was observed in the manual cleansing area, while the values remained similar to baseline values in the area where the sonic device was used.

Conclusion: The cleansing process with a sonic device did not cause a significant hydration reduction, suggesting better preservation of skin homeostasis when compared to manual cleansing.

KEYWORDS
facial cleansing, skin barrier, skin bioengineering, sonic device

1 | INTRODUCTION

Skin is an important organ that acts as a physical and chemical barrier. Its protective role is essential for the maintenance of homeostasis through the balance of several physiological parameters, including transepidermal water loss, hydration of the stratum corneum, lipid content, and pH.[1]

Among these factors, the amount of lipids secreted by the sebaceous glands on the skin surface significantly contributes to skin barrier formation and the antioxidant and antibacterial effects.[2] However, when excessive lipid is synthesized and excreted, dermatological problems may occur, such as seborrheic dermatitis and acne, in addition to aesthetically unwanted oily skin.[2] Removing excess oil and dirt from the skin with specific cosmetic products is a very important process that complements the treatment of various dermatological conditions.[1,3]

However, skin cleansing with products of high surfactant content can reduce the natural moisturizing factor (NMF) and epidermal intercellular lipids, resulting in xeroderma and other clinical manifestations.[2,4,5]

For this process to be beneficial and maintain skin homeostasis, cosmetic products must ensure a proper balance between removing dirt and excess surface lipids and maintaining hydration of the stratum corneum, the outermost layer of the skin.[1,3]

Considering the growing concern about facial care, several physical mechanisms, such as sonic devices, have been developed to be combined with cosmetic products, promising to facilitate and improve the efficiency of the cleansing process.[3,6] Sonic brushes promote facial cleansing through oscillatory movements without exceeding the skin physical limits. The repetition of these oscillatory movements in appropriate frequency and amplitude ranges results in a more efficient pores unblocking.[6]

Skin bioengineering is an adequate method to analyze and confirm the benefits of these cosmetic and/or aesthetic products, as it assesses the functional and physiological parameters of the skin in a noninvasive manner, in real conditions of product use.[7]

Combined with biometric methods, image analysis is an important noninvasive tool in the study of effectiveness, widely applied in clinical practice. In this context, infrared thermography is a technique that produces graphical records of temperature measured in different areas of the body by detecting its infrared radiation; the records are quantitatively displayed on a visible color scale. These images reflect the dynamics of skin microcirculation which allows simultaneous measurements of skin temperature in different areas.[8]

This study aimed to assess the effect of facial cleansing on the physiological properties of the skin, comparing the cleansing process with a cosmetic product applied manually to cleansing with a cosmetic product combined with an electric sonic device using skin bioengineering and skin imaging techniques.

2 | METHODS

2.1 | Experimental design

This open comparative randomized controlled clinical study was conducted in a temperature-controlled room at the School of Pharmaceutical Sciences at Unicamp. This study was approved by the Research Ethics Committee of the School of Medical Sciences at Unicamp.

After signing an informed consent form (ICF), 12 women of mean age 22 ± 10 years were included in the study and instructed not to wash the skin test area for at least 2 h before the assessment. The participants were acclimated to a constant temperature of 20 ± 2°C and a relative humidity of 50 ± 5% RH, 20 min before starting instrumental measurements performed in these environmental conditions.[7]

Exclusion criteria included cognitive and verbal limitations and allergic reactions to the cleansing product.

Sebummetry, corneometry, and TEWL parameters were measured by a trained operator in the frontal region of the face of every participant before (T0), 15 min (T15), 40 min (T40), and 90 min (T90) after cleansing. In addition, imaging analysis through 50 MHz ultrasound was performed at T0 and T90. Thermal imaging was obtained before product application (T0) and immediately after each type of cleansing (with and without an electric brush) to assess facial temperature.

Using simple randomization, each participant's hemiface (right or left) was allocated to each cleaning method: manual or with sonic device. In the test area, 0.5 g of a gentle skin cleanser was applied. Table 1 shows the qualitative composition of this lotion. Then, the product was spread with a sonic device for 15 s on each region of the face. In the control side of the face, the same amount of the cleansing lotion was applied and spread manually with circular movements for other 15 s in each region (total time: 1 min on each half of face).

TABLE 1 Cleansing lotion components and their functions

Components	Function
Deionized water	Vehicle
Sodium lauryl sulfate	Anionic surfactant
Stearyl alcohol	Emollient and donor of consistency
Cetyl alcohol	Emollient and donor of consistency
Propylene glycol	Humectant
Methyl-, propyl-, butylparaben	Preservatives

2.2 | Biometric assessments

Water content of the stratum corneum was determined with Corneometer® CM 825 (Courage + Khazaka electronic GmbH, Köln, Germany), while skin oiliness was assessed using the photometric method with Sebumeter® SM 815 (Courage + Khazaka electronic GmbH, Köln, Germany). These assessments were performed on the right and left frontal regions. The skin barrier effect was evaluated using Tewameter® TW 210 (Courage + Khazaka electronic GmbH, Köln, Germany) on the right and left malar regions. These procedures were performed according to protocols described by Barel and Clarys[7] and Rogiers.[9]

2.3 | Thermographic assessment of the skin

Infrared thermography (IRT) was used for thermographic characterization of the skin using electric brushes. The analysis was performed using Flir One® Pro (FLIR® Systems, USA) thermal camera. With this technique, infrared imaging is acquired of any object above −273°C emitting electromagnetic radiation. Human skin has constant emissivity at this wavelength, so thermography is an ideal method for assessing the temperature of the skin surface.[10]

The distance of 40 cm above the participant was standardized to position Flir One® Pro camera (FLIR® Systems, USA) and obtain thermal imaging.

2.4 | Image analysis using high-frequency ultrasound

Ultrasound imaging was obtained using 50 MHz Dub®SkinScanner (TPM® taberna pro medicum, Germany). This equipment generates electric pulses that are converted into ultrasound signals by a high-frequency ultrasound transducer. The signals are transmitted on the skin and tissue non-homogeneity due to cell formation and blood vessels, for example, produce reflexes and echoes that are captured by the same transducer and changed into an electrical signal. The signals are processed, generating high-resolution, high-contrast imaging.[11]

The parameters of epidermal and dermal echogenicity, subepidermal low-echogenic band (SLEB), skin thickness, and surface roughness were evaluated using DUB-SkinScanner75 5.26 software (TPM® taberna pro medicum, Germany).

2.5 | Statistical analysis

Data were presented as mean, standard deviation, and percentage.

Relative percent differences (RPD) of the biometric and infrared thermography parameters were calculated using the formula below:

$$\text{RPD}\,(\%) = \left[(\text{Qt} - \text{Q0})/\text{Q0}\right] \times 100$$

where

Qt = biophysical measurements made in time intervals after cleansing, and

Q0 = biophysical measurements made at T0.[5,12]

An exploratory analysis was performed of raw data obtained for each parameter. Product and control were compared at each time using two-way ANOVA with repeated measures followed by Fisher's post hoc test (LSD). When data did not show a normal distribution, the comparison was made using the Friedman test. A confidence level of 95% was considered, and the analyses were performed in GraphPad Prism 8 software (GraphPad, San Diego, LA, USA).

3 | RESULTS

3.1 | Biometric assessments

Figures 1 and 2 show the results of sebummetry obtained in this study.

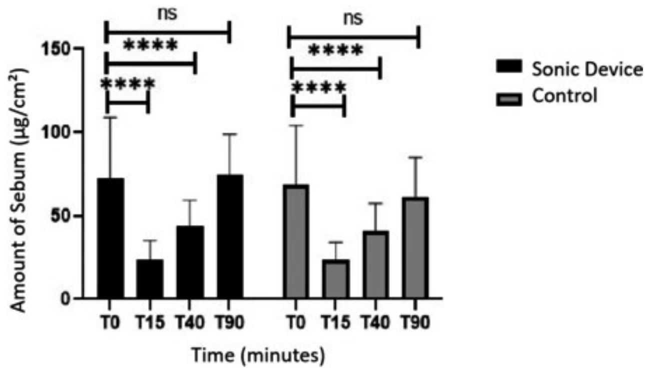

FIGURE 1 Comparative analysis between the means of sebummetry (µg/cm^2) when comparing cleansing types in relation to time. Values with differences are indicated with an asterisk (*), while values with no difference are indicated with "ns." For *p*-values above 0.05, the parameters did not differ significantly in relation to treatment (A) or time (B), at the significance level of 5%

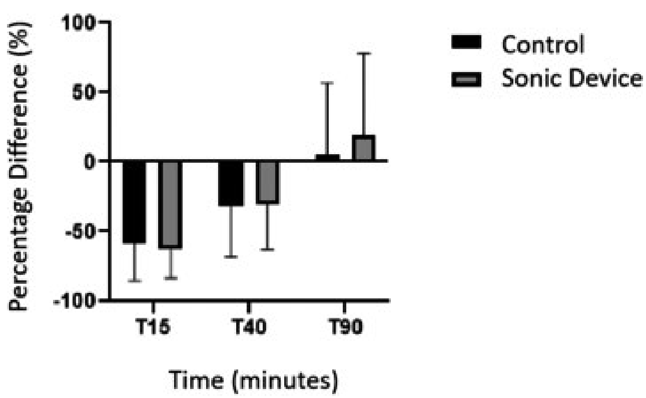

FIGURE 2 Percentage difference in sebummetry values after product application with and without an electric device in relation to time

The values of sebummetry (Figure 1) indicate that cleansing the halves of the face of every participant, either with or without a device, resulted in significant decrease of this parameter at T15. After facial cleansing, baseline oil levels are gradually recovered, as observed at T40 and T90. At T90, baseline levels are completely restored, with no significant difference between the sebummetry values presented at T0 and T90.[1,13,14] This restore occurred similarly in the two cleaning methods, suggesting no influence on skin oiliness with the use of a sonic device.

The analysis of sebum increase in the studied areas in relation to T0 (Figure 2) showed significant sebum reduction of 58.33% and 62.73% after 15 min of facial cleansing without and with the use of an electric sonic device, respectively. After 40 min, sebum levels increased proportionally in both types of cleansing until returning to baseline levels of sebum.

The evaluation of water content of the stratum corneum (corneometry) and transepidermal water loss (TEWL) after facial cleansing with and without an electric device is illustrated in Figures 3 and 4, and Figures 5 and 6, respectively.

According to data presented in Figures 3 and 4, a significant decrease in water content of the stratum corneum (17.19%) was observed after cleansing with manual massage (control area), suggesting reduced skin hydration. After 40 min, the capacitance measurements of the control area were still significantly reduced and reached baseline values at T90. On the other hand, Figure 4 shows that using an electric brush did not result in a significant decrease in hydration values when compared to baseline levels at any time after facial cleansing, remaining statistically equivalent to measurements made at T0.

The percent difference in raw data indicated in Figure 5 shows a higher increase of TEWL (5.58%) when compared to the area treated with the electric device (3.51%). After such increase in TEWL, the skin barrier tends to recover gradually, reestablishing the baseline levels (T0) of this biophysical parameter, as demonstrated at T40 and T90.

However, according to the statistical analysis, TEWL values did not show significant differences after cleansing with or without the electric device during the study period (Figure 6). This way, all TEWL measurements in the two types of cleansing remained equivalent to the values obtained at T0.

3.2 | Skin imaging assessments by thermography and high-frequency ultrasound

The quantitative results obtained from thermal imaging show baseline mean values of the temperature in the control and test areas (30.45°C ± 2.03 and 30.51°C ± 2.28, respectively) remained equivalent to those found after cleansing at T1 (30.12°C ± 2.61 and 30.14°C ± 2.95, respectively). In addition, no significant difference was found between the two types of cleansing at the studied times.

In the assessment of skin ultrasound images, our study did not show significant statistical differences in any evaluated parameter (echogenicity, thickness, SLEB, and roughness) after facial cleansing with or without a sonic device. In addition, the qualitative evaluation

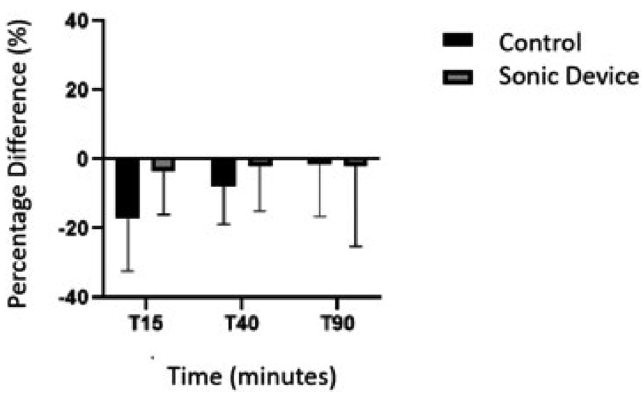

FIGURE 3 Percent difference of water content of the stratum corneum after product application with and without the use of an electric device in relation to time

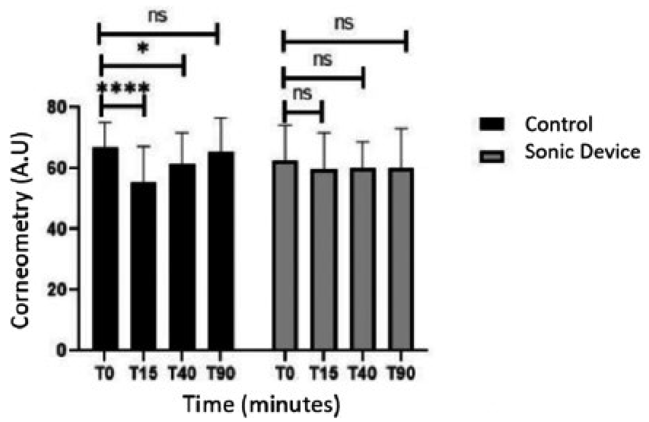

FIGURE 4 Comparative analysis between the means of corneometry (arbitrary units—AU) when comparing cleansing types in relation to time. Values with differences are indicated with an asterisk (*), while values with no difference are indicated with "ns." For p-values above 0.05, the parameters did not differ significantly in relation to treatment (A) or time (B), at the significance level of 5%

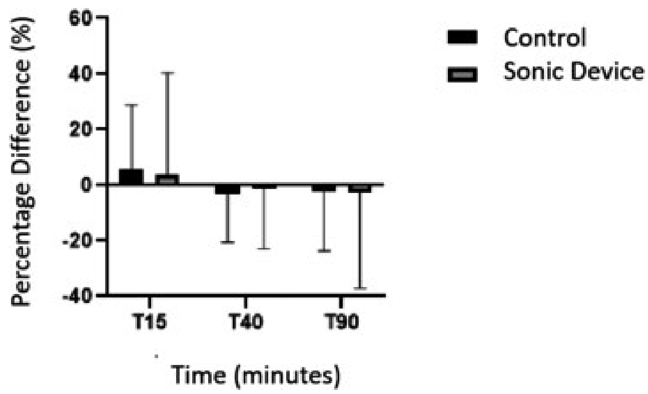

FIGURE 5 Percent difference of TEWL values after product application with and without the use of an electric device in relation to time

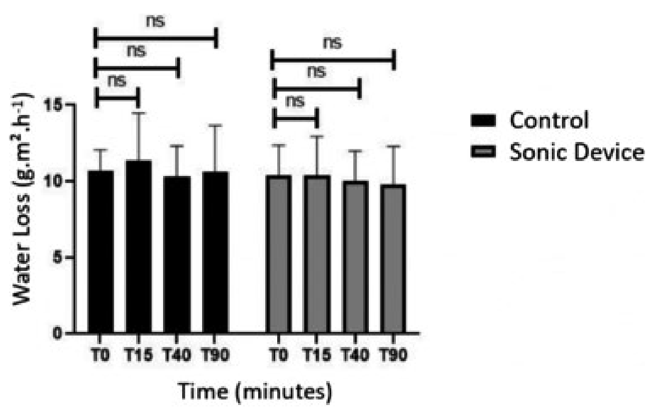

FIGURE 6 Comparative analysis between means of TEWL ($g.m^2.h^{-1}$) when comparing cleansing types in relation to time. Values with differences are indicated with an asterisk (*), while values with no difference are indicated with "ns." For *p*-values above 0.05, the parameters did not differ significantly in relation to treatment (A) or time (B), at the significance level of 5%

of images also did not show changes in any structural pattern of the skin (Figure 7).

4 | DISCUSSION

4.1 | Biometric assessments

Facial cleansing is very important for personal care and elimination of dirt, dead cells, residual cosmetic products, and, mainly, excess oil.[3,15] However, the cleansing agents used in this process did not show the natural lipids present in the skin, which are important for maintaining skin hydration, such as ceramides, cholesterol, and cholesterol esters. Removing these lipids can impair the barrier function of the epidermis and increase the transepidermal water loss to the environment. Several problems can occur in the skin due to reduced ability of water retention in the epidermis, such as xeroderma.[1,14,15]

Thus, the reduction of sebummetry values (Figure 1) is caused by the action of the surfactant present in the cleansing lotion (sodium lauryl sulfate), an amphiphilic molecule that solubilizes lipids, removing the surface oil.[5]

Sebum production and excretion dynamics involves four main steps: sebum production by the sebaceous gland (secretion), deposition in the infundibulum, excretion on the skin surface, and presence in the stratum corneum.[13]

With the removal of the lipid film, the amounts of sebum excreted on the skin surface increase in the first 3 h. This excretion rate tends to decrease after this period until reaching a plateau, a condition referred to as casual sebum level.[13]

Restoration of baseline levels of surface oiliness (casual level), after its removal, occurs due to the movement of accumulated sebum in the infundibulum by capillarity. Therefore, restoration is not a consequence of increased sebum production since the cleansing process does not alter gland activity.[13] In addition, the use of a mild cleansing lotion ensures a gentle removal of sebum from oilier areas, such as the frontal region of the face, with oil returning more quickly as observed in Figures 1 and 2.[16]

Although the differences between the mean values at T90 (Figure 2) were not statistically significant, prior studies suggest that

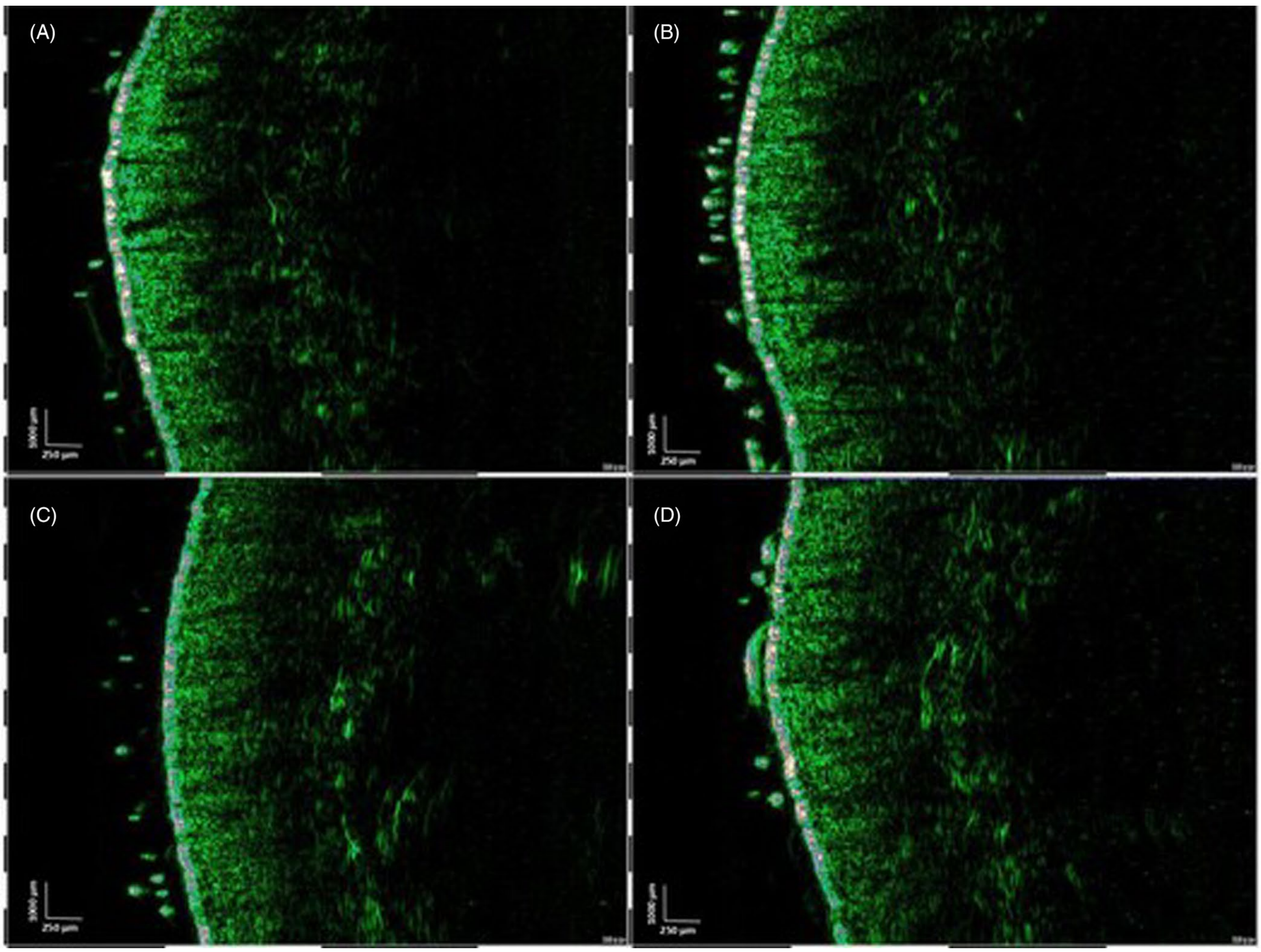

FIGURE 7 High-frequency ultrasound imaging of the test area (using a sonic device) before (A) and after (B) cleansing and the control area before (C) and after (D) manual cleansing

vibratory movements of the device around the infundibular opening allow greater follicular clearance, resulting from the accumulation of dirt, cornification products, sebum secretions, microorganism products, and cosmetic product residues.[6,17–19]

As discussed, the cosmetic products used in the cleansing process have high concentrations of surfactants which interact with lipids and proteins of the stratum corneum and remove NMF. The extent of epidermal barrier function impairment and changes in hydration of the stratum corneum depend on factors such as surfactant nature; frequency of exposure to these agents; cleansing conditions, including water temperature and humidity; and product composition.[14,20]

In the short term, cleansing products can reduce the water retention capacity of the stratum corneum so hydration changes are sensorially perceived. With a higher frequency of cleansing, the skin barrier integrity is continually compromised, leading to greater TEWL and clinical manifestations such as xeroderma, scaling, erythema, and itching. Damages resulting from this process can be mitigated with less aggressive surfactants or through the deposition of humectant, emollient, and occlusive substances.[2,14,15,17]

Data obtained in this study show reduced hydration of the stratum corneum after cleansing with manual massage, possibly due to the interaction of anionic surfactant with proteins and the removal of NMF.[14]

However, the use of an electrical device may have increased the efficiency of detaching dirt trapped in sebum, ensuring its interaction with a greater amount of surfactant molecules.[6,18] Thus, there is a reduction in the amount of remaining amphiphilic molecules available to interact with other skin constituents—such as natural skin humectants, contributing to the maintenance of electrical capacitance values. In addition, sonic oscillatory movements may be causing an increase in skin microcirculation that is indirectly related to its hydration.[21]

According to the literature, the application of sonic technology combined with cleansing cosmetics offers a safe alternative that contributes to skin barrier integrity.[3] Then, these electrical devices, when used with proper frequency and amplitude, optimize the cleansing process by using the elastic properties of the skin, without irritating it or exceeding its physical limits.[3,6,17,18]

The presence of dry skin is not necessarily related to an increase in transepidermal water loss, suggesting that low hydration values are not necessarily associated with significant damage to the barrier. Accentuated damage and higher TEWL values can be observed in studies that assess the effects of frequent cleansing over a longer period, and this parameter must be associated with other biophysical analyses to obtain more reliable results.[14,20] Then, the short study period combined with the action of the emollients of product formulation used in this study possibly prevented significant differences in the values of TEWL after cleansing with or without the use of an electric brush.

4.2 | Skin imaging assessments by thermography and high-frequency ultrasound

Mechanical stimulation on skin surface with different devices or manual procedures can cause beneficial cosmetic effects, including increased blood circulation.[22]

Human face temperature varies according to the area, as illustrated in Figure 8. Such heterogeneity is probably due to the presence of low metabolism tissues located under the face, such as connective and bone tissue, leading to a variation of heat transfer

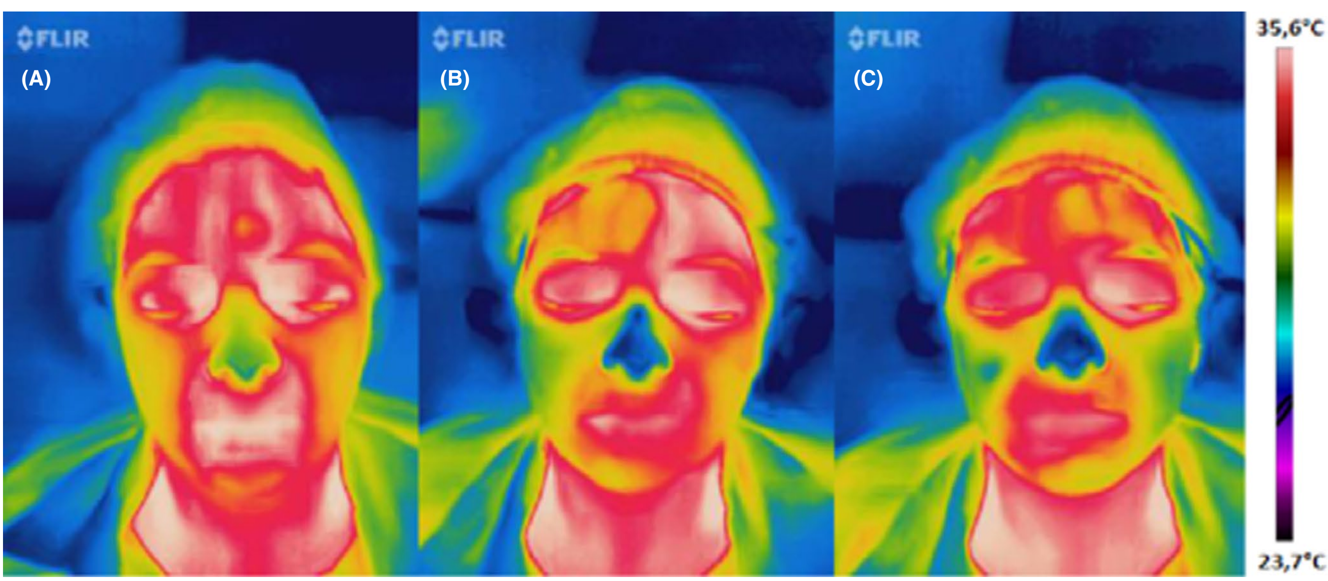

FIGURE 8 Thermal imaging obtained before product application (A) and immediately after manual cleansing on the right side of the face (B) and using the electric device on the left side of the face (C)

by convection to the skin surface. These temperature differences present an uniform distribution, simultaneously on both sides of the face, since the thermal effects tend to occur symmetrically all over the body.[8]

In this study, skin temperature assessment was probably influenced by the physical principle of evaporative cooling, where the evaporation of water and other volatile substances present in the applied product causes reduces skin temperature for a short period of 5–15 min.[23] Then, the action of a sonic device on the skin could be better studied by infrared thermography without the application of cosmetics, avoiding the interference of this phenomenon in the analysis.

In addition to the thermal effects, other physiological changes in the skin resulting from mechanical forces can be evaluated.

Carbelotto et al.[24] demonstrated in an *ex vivo* study, an oscillatory mechanical stimulus under experimental conditions was able to increase the expression of proteins of the dermoepidermal junction and the production of elastic fibers and produce histological structural changes in the papillary dermis after 10 days. The frequency of electrical stimulation proved to be an important parameter for these results. In an *in vivo* analysis of this study, the time of device use influenced the analysis of its effectiveness, with clinical improvement of the skin condition starting in week 4.

Dermal and epidermal changes and skin tissue characterization can also be assessed by *in vivo* evaluation of ultrasound parameters, since these parameters have a sensitive relationship with the content and organization of collagen bundles, as well as other tissue components.

Ryan et al.[25] demonstrated an increase in epidermal and dermal water content after the application of a vibrational stimulus for 10 min by SLEB detection.

Considering prior studies, the results obtained in our study were possibly due to the short period of sonic device application, which may have been insufficient to detect noticeable changes in ultrasound analysis.

4.3 | Limitations and perspectives for further studies

The application of the cosmetic may have interfered with the skin temperature. This parameter could be better studied on the skin without the cleansing product. The force applied in rubbing the skin in both areas (manual or with sonic device) must also be considered as a possible bias.

Further studies should be encouraged to assess skin effects after several cleansing processes or cleansing on consecutive days since, under these conditions, changes in the skin barrier tend to be more significant and can be better evaluated.[14] Studies conducted in longer periods may allow a better prediction of chronic effects of this procedure.[20] In addition, other formulations with different cleaning potentials can be further investigated in works with similar objectives.

5 | CONCLUSION

The same skin oiliness profile was identified for both cleansing processes (with or without using a sonic device). There were no differences in the TEWL, ultrasound, and thermography assessments before and after cleansing. Significant reductions in water content of the stratum corneum were found in the control area (area without electric device). However, the electric device did not change electrical capacitance values, which remained equivalent to baseline, suggesting a better maintenance of skin homeostasis right after the cleansing procedure. Therefore, the use of the electric device associated with cleansing formulations can contribute to a smoother skin cleansing process.

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CONFLICT OF INTEREST

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AUTHOR CONTRIBUTIONS

All authors were involved in the work leading to the publication of the paper, which was read and approved by all of them. Each author's contribution is listed below: Laura Moretti Aiello: contributed to the acquisition and interpretation of data and drafting the paper. Mariane Massufero Vergilio: contributed to the acquisition and interpretation of data. Silas Arandas Monteiro e Silva: contributed to the translation of the final text and revising it critically for important intellectual content. Tamiris Anselmo: contributed to the acquisition and interpretation of data. Gislaine Ricci Leonardi: contributed to conduct the research and approval the final manuscript.

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