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The use of silica biomicroneedles in acne therapy. Analysis of skin parameters

Zastosowanie biomikroigieł krzemionkowych w terapii trądziku. Analiza parametrów skórnych

ABSTRACT

Silica biomicroneedles are obtained from sponge skeletons through hydrolysis, purification, and appropriate drying. They are used in regenerative medicine and cosmetology to promote active substance absorption and a physical stimulus that triggers a cascade of repair processes through a puncture mechanism.

The study aimed to evaluate the effectiveness of acne therapy using silica biomicroneedles.

Statistically significant improvement was observed in all parameters tested, including a reduction in the number of acne lesions. Imaging diagnostics showed a decrease in inflammation, porphyrins, and sebaceous gland activity.

The therapy showed potential as an effective, non-invasive adjunct to acne treatment, especially with appropriate qualification and a holistic approach.

Keywords: acne vulgaris, silica biomicroneedles, skin, echogenicity, seborrhea, epidermal barrier, TEWL

STRESZCZENIE

Biomikroigły krzemionkowe pozyskiwane są ze szkieletów gąbek w procesie hydrolizy, oczyszczania i odpowiedniego suszenia. Stanowią materiał wykorzystywany zarówno w medycynie regeneracyjnej, jak i kosmetologii, jako promotor wchłaniania substancji aktywnych oraz bodziec fizykalny uruchamiający kaskadę procesów naprawczych poprzez mechanizm nakłucia.

Celem badania była ocena skuteczności terapii trądziku z wykorzystaniem biomikroigieł krzemionkowych.

Uzyskano istotną statystycznie poprawę wszystkich badanych parametrów, w tym redukcję liczby zmian trądzikowych. Diagnostyka obrazowa wykazała zmniejszenie stanu zapalnego, redukcję porfiryn oraz spadek aktywności gruczołów łojowych. Terapia wykazała potencjał jako skuteczne, nieinwazyjne wsparcie leczenia trądziku, szczególnie przy odpowiedniej kwalifikacji i podejściu holistycznym.

Słowa kluczowe: trądzik pospolity, biomikroigły krzemionkowe, skóra, echogeniczność, łojotok, bariera naskórkowa, TEWL

INTRODUCTION

Acne is an aesthetic problem that significantly affects the quality of life of people who suffer from these skin changes [1, 2]. Due to the multitude forms of the disease and its diverse and often difficult-to-diagnose etiology, acne is frequently associated with long-term therapies, usually with unsatisfactory results and low efficacy [3]. Using silica biomicroneedles is an innovative approach to acne therapy [4, 5]. Known for over 500 years, bio-microneedles – silica spicules derived from sponge skeletons – have been used in medicine for centuries and, more recently, in regenerative cosmetology [6]. Their potential to transport active ingredients and induce controlled inflammation through microneedling allows for a wide range of applications in skin therapies [7, 8]. Scientific research confirms the anti-inflammatory and regenerative

effects of silica needles, emphasizing the high safety profile of the treatment in case of high-quality marine material – highly purified, uncrushed raw material [9]. Given their properties, spicules may be a promising alternative to traditional pharmacological therapies or an adjunctive treatment for acne [10].

AIM OF THE STUDY

The study aimed to evaluate the effectiveness of acne therapy using silica bio-microneedles. A series of four treatments was performed at weekly intervals. The effectiveness was assessed by skin parameter measurements, including echogenicity, thickness, transepidermal water loss (TEWL), sebum level, acidity/ alkalinity, pH, and moisture content, based on multispectral diagnostics and subjective assessment of the participants.

MATERIAL AND METHODS

Study group

The study involved 10 people (8 women, 2 men) with Fitzpatrick skin types I-III, aged 14 to 32, living in a large city with a population of over 500,000. The subjects were selected based on oily skin, blackheads, and acne. Each participant completed a statement confirming that their living conditions would remain unchanged during the study.

Methodology

Each of the participants underwent four treatments at intervals of seven days using a set of bio-microneedles. Skin parameters were measured before the first treatment, before the third treatment (on the day of the third treatment), and one week after the fourth treatment. The following parameters were analyzed: echogenicity, skin thickness using high-frequency ultrasound (UHF-USG, 48 MHz), sebum level (by sebumeter), skin pH (by pH-meter), moisture (by corneometer), TEWL (by tewameter), and the number of acne lesions. The same parameters were examined on the neck, which was not subjected to treatment (control sample). In addition, a subjective assessment of the participants' satisfaction after the series was completed and taken into account (on a scale of 1-10, where 1 meant high dissatisfaction and 10 was high satisfaction).

- **Echogenicity**. The ability of tissues to reflect ultrasound waves depends primarily on their composition, density, and fluid content. Knowledge of the physiological and pathological processes occurring within the examined tissue, especially the course of the inflammatory response and its differentiation from normal hydration, is of key importance in interpreting the results obtained.
- **Skin thickness**. This is an important parameter in assessing the effectiveness of cosmetic and aesthetic treatments, especially those aimed at improving skin firmness and tissue remodelling. Thanks to the use of high-frequency ultrasound, it is possible to non-invasively and precisely monitor changes in the skin structure at various stages of the therapy. Skin thickness measurement allows to objectively assess the skin's response to the treatment and potential collagen layer remodelling.
- **Sebumetry**. It enables the measurement of sebum (µg/cm^2) produced by the sebaceous glands. It analyses the decrease in light transmission through a transparent tape applied to the tested area.
- **pH-metry**. It determines the pH, i.e. the negative logarithm of the hydrogen ion concentration. This parameter enables assessing the skin's surface reaction and thus its barrier function in the tested area. Physiologically, within the stratum corneum of the facial skin, it should be slightly acidic (approximately 4.1-5.8). Lowering the skin's pH can have a beneficial effect on the skin's microbiome.
- **Corneometry**. A non-invasive method for measuring the moisture level in the stratum corneum, commonly used in skin research. This parameter allows for quantitative assessment of skin hydration, which is crucial in evaluating the effectiveness of treatments that improve the hydrolipid barrier. Regular corneometric measurements allow to track changes in the moisture level of the stratum corneum over time and are a valuable supplement to the clinical evaluation of the effects of the therapy. Corneometry is based on the measurement of the electrical capacitance (dielectricity) of the skin, which changes depending on the water content in the stratum corneum. The corneometer emits a weak electric field and measures its change in contact with the skin. Water has a high dielectric constant ($\varepsilon_r \approx 78.5$, at 25°C and 1 MHz), so the higher the water content in the epidermis, the greater the dielectric capacity recorded by the sensor. The result is presented in arbitrary units (AU), which allows for comparison of moisture levels before and after treatment.
- **Tewametry**. It involves measuring the amount of water evaporating from the skin surface, which penetrates from the deeper layers of the epidermis towards the environment according to the concentration gradient. The tewameter measures this process based on changes in relative humidity and air temperature at two points (sensors) located in a measuring chamber just above the skin. TEWL is expressed in units of g/m^2/h (grams of water evaporated per square meter of skin per hour), and the device assumes diffusion according to Fick's law – the amount of water flowing through a unit of surface area depends on the difference in concentration (humidity) between the skin and the environment. The TEWL level is usually inversely proportional to the level of skin hydration.
- **Multispectral analysis**. An imaging technique that uses light of different wavelengths: from ultraviolet (UV) radiation, through visible light, to near-infrared, to obtain a detailed

image of the skin structure. In diagnostics, a Wood's lamp is used, among other things, to image porphyrins (metabolites of opportunistic bacteria), discoloration, and skin hydration. Cross-polarization allows for the visualization of erythematous or inflammatory changes, while parallel polarization is used to assess the three-dimensional texture of the skin, including wrinkles and scars.

The treatments were performed according to a strictly defined procedure.

1. Skin cleansing.
2. Massaging in the oil serum.
3. Kneading the mixture of bio-microneedles and activator for 10 minutes (kneading motion).
4. Removal of residues.
5. Application of a post-treatment mask for 10 minutes.

The participants also received a home care kit: a regenerating serum to be applied twice a day throughout the study cycle and a cream to maintain the results, to be used after the final measurement.

The statistical analysis included the following steps.

- Calculation of mean values and standard deviations for each parameter before and after the end of therapy.
- Checking the data distribution using the Shapiro-Wilk test to verify the parametric assumptions.
- A Student's t-test for dependent samples (paired samples t-test) was used to compare the values before and after treatment in the case of normal data distribution.
- A p-value of <0.05 was accepted as the level of statistical significance.
- For a better illustration of the changes, box plots showing the parameter values before and after therapy were created.
- Analyses and visualizations were performed using the Python package (libraries: pandas, scipy, seaborn, matplotlib).

RESULTS

All parameters showed a statistically significant improvement after the end of therapy.

Echogenicity

A statistically significant increase in echogenicity was demonstrated (fig. 1, 2). In the inflammatory phase, increased intercellular fluid leads to a decrease in echogenicity, which reflects as elevated tissue hydration. As the healing process progresses to the proliferation and remodelling phase, fluid resorption, cell proliferation, and deposition of new protein fibers occur. These structural changes cause an increase in tissue density, which results in a higher level of ultrasound wave reflection, i.e., augmented echogenicity.

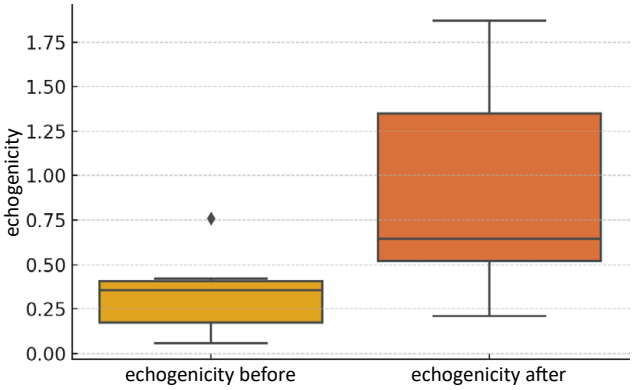

Fig. 1 Change in echogenicity [%] of the skin after a series of four treatments with silica bio microneedles **Source:** Own elaboration

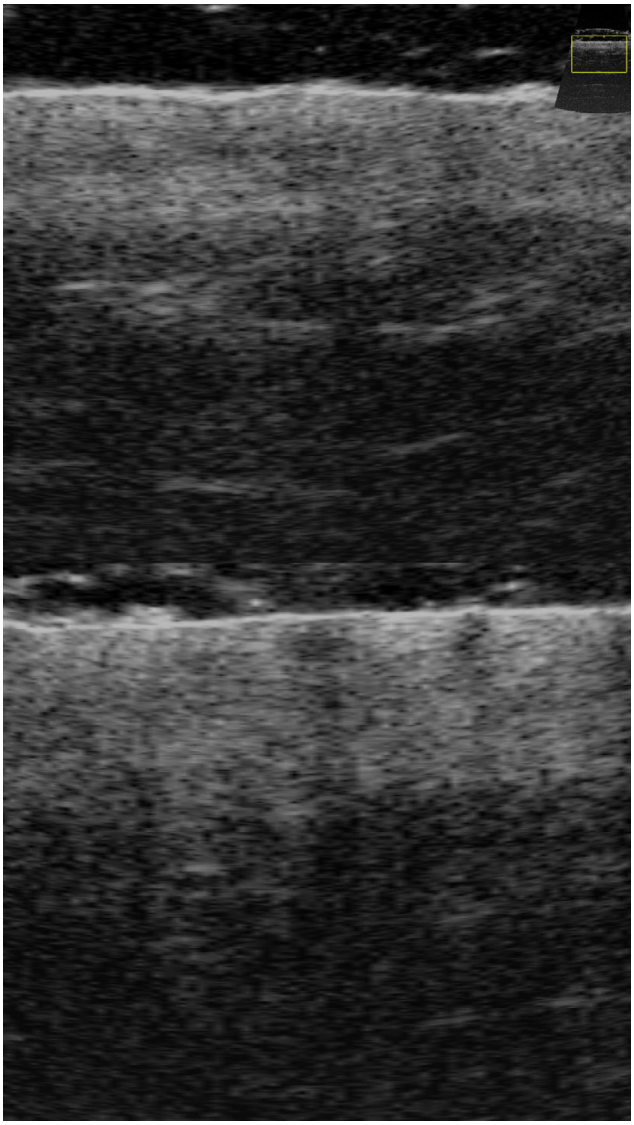

Fig. 2 Change in skin ultrasound image. Upper part, photo taken before treatment; lower part – after a series of four treatments with silica bio-microneedles. **Source:** Own elaboration

Thickness

The study showed a statistically significant increase in skin thickness [mm] (fig. 2, 3), which suggests the activation of regenerative processes.

Sebumeter

A statistically significant decrease in sebum production was demonstrated (fig. 4), indicating a reduction in seborrhea as a result of sebum regulation associated with improved skin barrier function and reduction of inflammation.

Skin pH

A statistically significant decrease in pH was observed in the treated area (fig. 5). Acidification of the environment prevents the proliferation and growth *of Cutibacterium acnes*, while promoting the colonization of the skin by physiological commensals.

Corneometry

Increased hydration of the stratum corneum was demonstrated (fig. 6). The boost in hydration indicates an improvement in the barrier function of the epidermis.

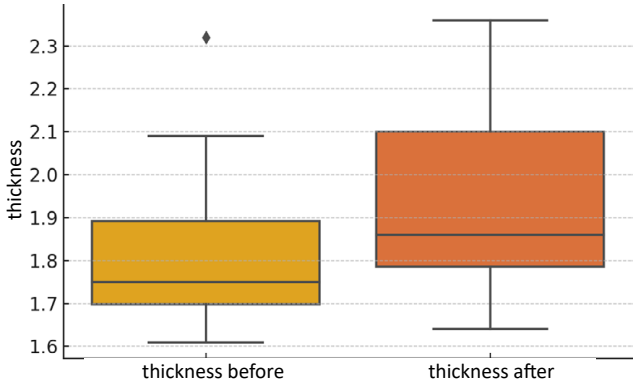

Fig. 3 Change in skin thickness [mm] after a series of 4 treatments with silica bio-microneedles **Source:** Own elaboration

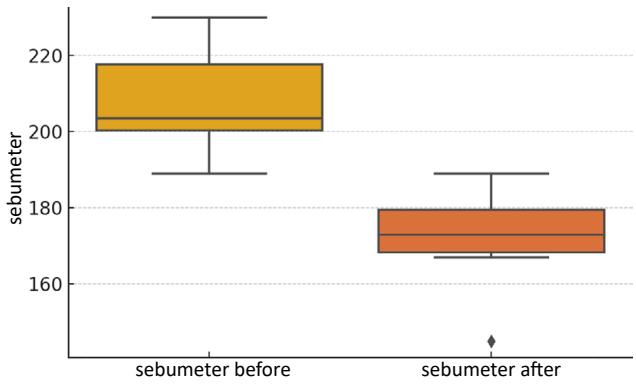

Fig. 4 Change in sebumetry values after a series of four treatments with silica bio-microneedles **Source:** Own elaboration

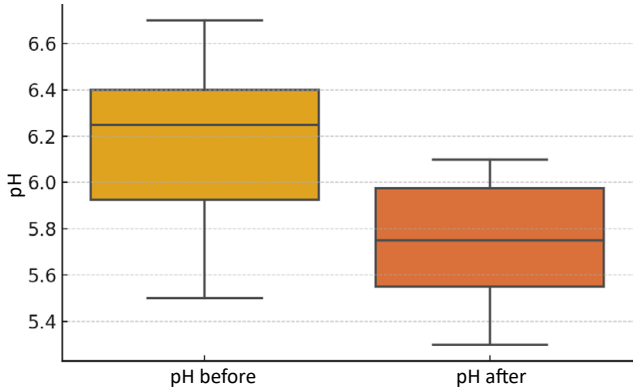

Fig. 5 Change in skin pH after a series of 4 treatments with silica bio-microneedles **Source:** Own elaboration

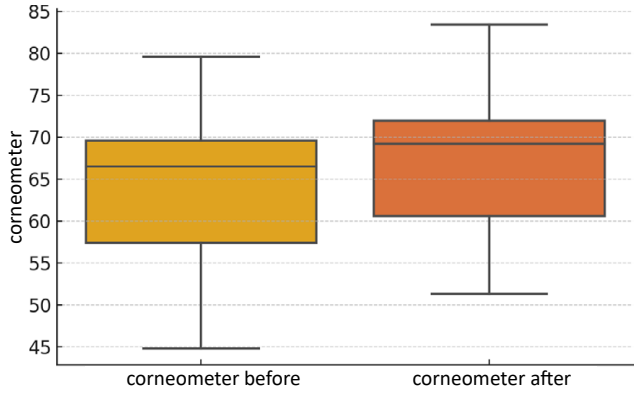

Fig. 6 Change in stratum corneum hydration after a series of 4 treatments with silica bio-microneedles **Source:** Own elaboration

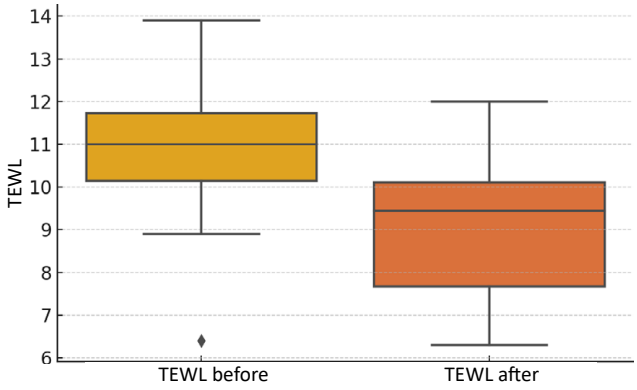

Fig. 7 Change in TEWL after a series of 4 treatments with silica bio-microneedles **Source:** Own elaboration

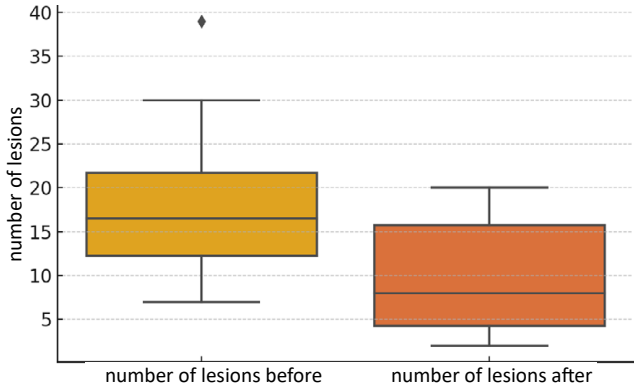

Fig. 8 Change in the number of acne lesions in the examined area after a series of 4 treatments with silica bio-microneedles **Source:** Own elaboration

Tewametry

A statistically significant reduction in TEWL was demonstrated (fig. 7), suggesting restoration of the skin's protective barrier. The parameters indicate a causal relationship: a reduction in bacterial colonization as a result of a decrease in pH → inflammation suppression → restoration of barrier functions → improvement in sebum regulation → and a reduction in TEWL.

Number of lesions

A reduction in the number of acne lesions in the tested area (number of lesions on the face) was demonstrated (fig. 8). The result confirms the effectiveness of the therapy and is the outcome of the changes in the parameters demonstrated during the measurements.

Multispectral diagnostics

Imaging diagnostics confirmed the results observed in the measurements. The comparative images show, among other things, a reduction in the area of orange fluorescence under a Wood's lamp, which indicates a decrease in porphyrin levels (fig. 9 and 10), indirectly suggesting a reduction in the activity of *Cutibacterium acnes* bacteria. Another parameter demonstrated is a decrease in inflammation visible in cross-polarization (reduction in skin redness) (fig. 11).

Fig. 10 Reduction of porphyrins after a series of four treatments with silica bio-microneedles **Source:** Own archive

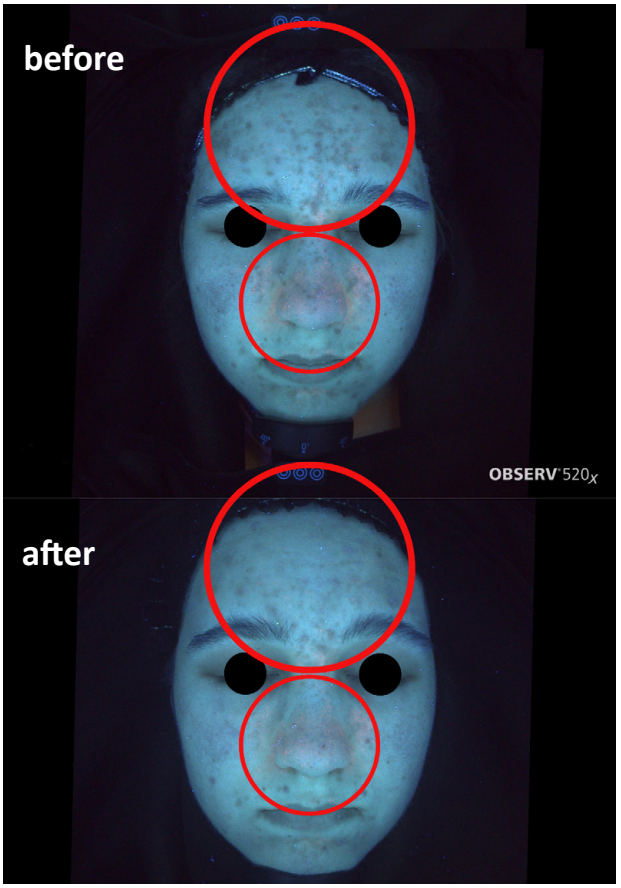

Fig. 9 Reduction of porphyrins and discoloration after a series of four treatments with silica bio-microneedles **Source:** Own archive

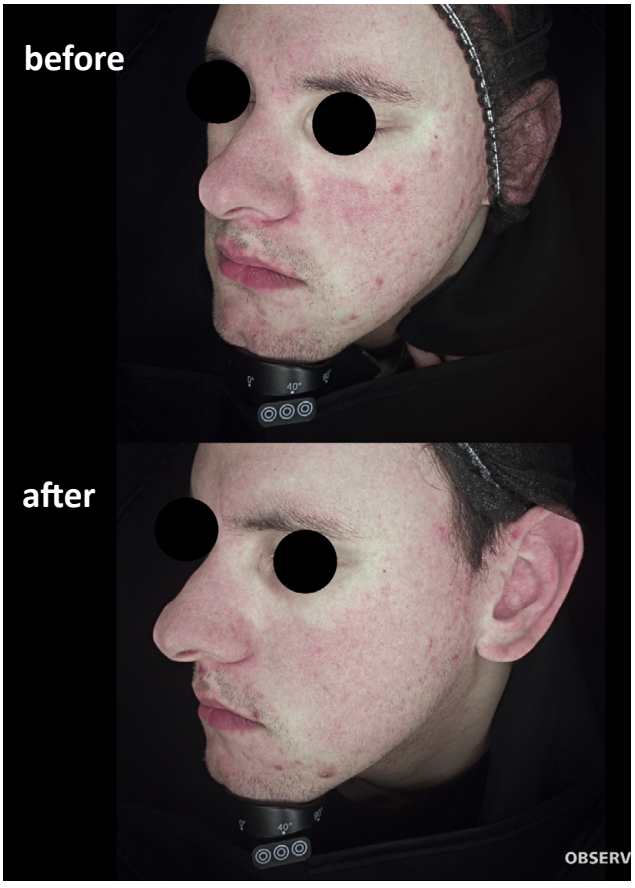

Fig. 11 Reduction of inflammation after a series of four treatments with silica bio-microneedles **Source:** Own archive

Fig. 12 Reduction of acne lesions in the forehead area after a series of four treatments with silica bio-microneedles **Source:** Own archive

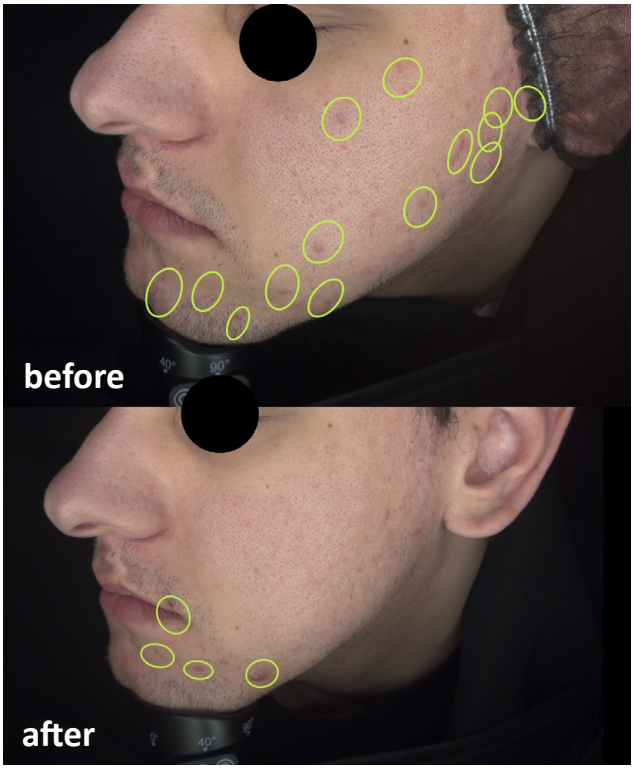

Fig. 13 Reduction of acne lesions on the left side of the face after a series of four treatments with silica bio-microneedles **Source:** Own archive

In addition, there was a reduction in the number of acne lesions in the examined area (fig. 12 and 13) as well as a decline in the size of the sebaceous glands and a decrease in sebum levels. Furthermore, multispectral analysis showed a reduction in discoloration (fig. 9).

Customer satisfaction

The average level of customer satisfaction after a series of treatments was 8.6 on a scale of 1-10, which indicates high acceptance of the therapy and a subjective improvement in skin condition. In people with acne caused by, among other things, hormonal disorders, the improvement was short-lived, and without treatment, the skin changes returned. This suggests the need for synergy between the therapy and systemic treatment in cases of functional disorders of the body.

Table 1 Changes in skin parameters

Parameter	Average before treatment	Average after treatment	Difference	Change (%)
Echogenicity [AU, *arbitrary units*]	0.32	0.89	0.57	178.13%
Thickness [mm]	1.83	1.94	0.11	6.01%
Sebum meter [µg/cm²]	207.8	173.1	-34.7	-16.7%
pH	6.17	5.74	-0.43	-6.97%
Corneometer [AU, *arbitrary units*]	64.06	67.87	3.81	5.95%
Tewameter [g/m²/h]	10.73	9.07	-1.66	-15.47%
Number of changes within the face	18.5	10.0	-8.5	-45.95%

Source: Own elaboration

Table 2 Subjective assessment of satisfaction of patients undergoing treatment

Person	Evaluation (1-10)
1	9
2	8
3	9
4	8
5	8
6	8
7	8
8	9
9	10
10	9

Source: Own elaboration

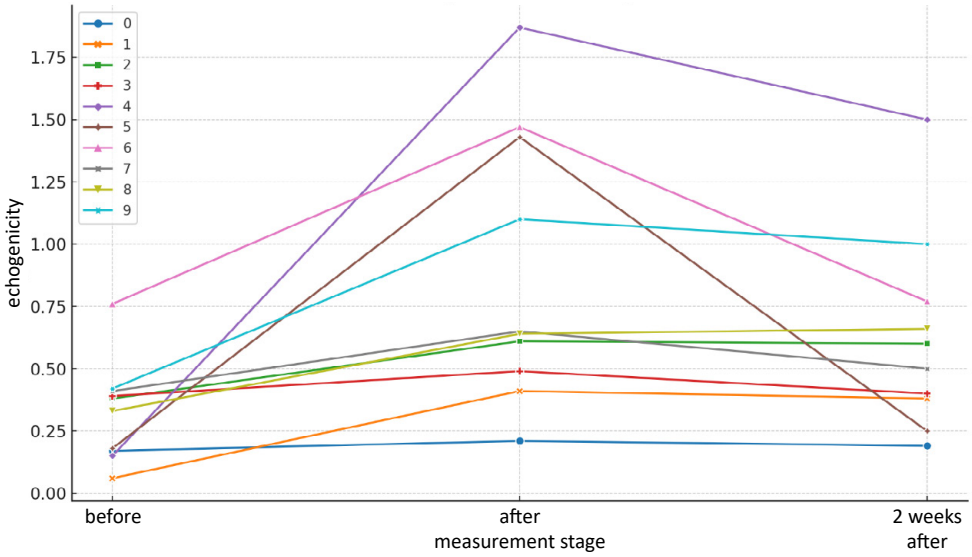

Fig. 14 Change in skin echogenicity over time **Source:** Own elaboration

POST-TREATMENT CARE

One week after the end of the treatment series, on the day of skin parameter measurements, participants were given a cream to use at home twice a day.

A follow-up measurement to determine whether home care contributes to maintaining the effects of the therapy was performed two weeks after the start of home care.

The difference in echogenicity between the measurement immediately after the treatment and after two weeks of home care was not statistically significant ($p > 0.05$). This means that the effects of the treatment are partially maintained. Although echogenicity decreases slightly, this change is not significant enough to be considered regression.

Control test

A control test performed in the neck area not subjected to therapy showed no statistically significant changes in any of the parameters examined, emphasizing the effectiveness of the therapy.

DISCUSSION

Bio-microneedles (spicules) are a raw material obtained from hydrolyzed sponge skeletons. For years, they have been the subject of interest of researchers in both medicine and cosmetology, mainly due to their function as promoters of the penetration of active substances. They enable the skin barrier to be broken down and active ingredients to be transported deep into the skin, including the sebaceous glands [1]. As demonstrated in scientific studies, spicules can increase the penetration of active ingredients up to six times [10].

Importantly, in addition to intensifying the absorption of active substances, bio-microneedles also exhibit antibacterial and anti-inflammatory properties, which are crucial in therapies targeting acne-prone skin [10]. Moreover, these raw materials are characterized by low toxicity towards skin cells, which makes them a safe alternative or support for more invasive treatment procedures [1].

The results obtained in this study confirm the effectiveness of therapy using silica bio-microneedles (spicules) in reducing acne symptoms and improving overall skin condition [11, 12]. A statistically significant improvement in parameters such as echogenicity, TEWL, sebum level, and number of acne lesions supports earlier scientific reports on the effectiveness of bio-microneedling and transdermal delivery of active substances [3, 10].

The observed increase in echogenicity and skin thickness suggests the activation of regenerative processes and remodelling of the extracellular matrix (ECM), which has also been demonstrated in other studies using microneedling as a stimulus for neocollagenesis [4, 8]. In addition, a decrease in TEWL and an improvement in hydration levels indicate the restoration of skin barrier functions, which is particularly important in the context of chronic inflammation associated with acne [5].

It is also worth emphasizing the importance of subjective patient assessment, which was consistent with the observed clinical results and confirmed the high acceptability of the therapy [11].

CONCLUSIONS

The therapy brought real, objectively measurable results and was also positively evaluated subjectively by the test participants. All analyzed parameters indicate a cause-and-effect relationship involving the restoration of physiological skin function, reduction of inflammation, and decrease of the number of bacteria responsible for the formation of lesions [10].

The therapy may be an effective supplement and, in selected cases, an alternative to pharmacotherapy [3]. In patients with endocrine disorders, it is necessary to normalize hormone levels to achieve lasting effects [1].

During the study, a reduction in inflammation, regulation of sebaceous glands, restoration of the skin's barrier function, increased skin thickness, and reduced bacterial colonization were observed. All these factors contributed to a significant reduction in acne lesions [9, 11].

A comprehensive analysis has shown that in subjects with acne lesions caused by clear hormonal imbalances, the problem is recurrent, and treatment combined with home care only slightly reduces the lesions.

The preliminary results presented suggest the potential effectiveness of the proposed therapeutic approach and may constitute a starting point for further research into modern acne treatment strategies [6].

SUMMARY

The study confirms the effectiveness of silica bio-microneedles in the treatment of acne vulgaris. Significant changes in skin parameters such as echogenicity, TEWL, sebum level, and number of acne lesions were observed, indicating improved barrier function, reduced inflammation, and skin structure remodelling. The subjective assessment of patients correlated with the measurement results, further confirming the effectiveness of the therapy. In patients with hormonal acne, a comprehensive approach combining topical therapy with systemic treatment was found to be necessary. Therapy with the use of spicules may be a valuable supportive or alternative tool in the treatment of acne, but further studies with a larger group of patients are necessary to confirm the results obtained and refine the therapeutic protocol.

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