INTRODUCTION

Aging is an inevitable biological process, during which the activity of cells decreases and their regenerative capacity declines. These processes can be modified through treatment procedures in the field of esthetic medicine and cosmetology. Contemporary esthetic medicine has confirmed that formulations containing stem cells and growth factors have a favorable impact on the appearance of the skin due to improving and regenerating the skin structure, and at the same time enhancing its elasticity and firmness.1-3

The skin is the outer covering the human body. It is thinner in places less exposed to mechanical damage and thicker in places that are more exposed to potential damage. The skin consists of...
three layers. The epidermis is the outermost layer composed of stratified squamous epithelium. It protects the skin against mechanical stimuli. The reproductive layer responsible for intensive cell division as well as the cornification and desquamation processes are located deeper. The second layer is the dermis, which is highly vascularized and innervated. Containing elastic and collagenous fibers, it is resistant to pressure and stretching. The dermis is made up of various types of cells, including fibroblasts, histiocytes, mast cells, and pigment cells. The third deepest layer is the subcutaneous tissue, which is also highly vascularized and innervated. It consists of connective tissue and numerous adipose cells that make up the panniculus adiposus.4

Facial esthetics play a significant role in the assessment of the quality of life. The face ages more or less rapidly depending on genetic and external factors. One of the first signs of facial skin aging is dryness and unevenness under the eyes caused by a loss of the ability to bind water and retain it in the epidermis.5 According to the literature, the eye area is the first to be affected by aging processes and is susceptible to the influence of various external factors.6,7 The initial processes take place in the epidermis as the layers consisting of live cells become thinner and the thickness of the stratum corneum increases. In addition, the number of melanocytes is reduced, so the skin is less protected from UV radiation. Further processes occur in the dermis: The number of fibroblasts decreases and the elastic fibers expand, which decreases the skin’s elasticity and reduces its resistance to injuries. Other processes connected with aging include a flattening of the epidermal-dermal interface; a progression of the irreversible loss of cytoplasmic protrusions; and a decrease in the adhesion of the epidermis to the dermis and in the tone of facial muscles.8 It is therefore important to present the possibilities of instrumental pretreatment diagnosis for assessing the condition of various facial skin areas.

The aim of this study is to analyze skin parameters in various facial areas in adults over a wide age range.

2 | MATERIALS AND METHODS

The study was conducted on 72 people, volunteers recruited among patients who sought treatment at the Facial Aesthetic Centre of the Poznan University of Medical Sciences. The measurements were carried out with the consent of the Bioethics Commission and follow the tenets of the Declaration of Helsinki. The patients were divided into two groups according to age but regardless of gender: those between 25 and 40 years old, and those between over 40 and 55 years old. The average age of the patients in the 25-40 group was (31.4 ± 4.5) years and the median equal 32 years, and in the 40-55 group (47.1 ± 5.0) years and the median equal 49 years.

The firmness and elasticity of the facial skin were tested using a Cutometer Dual MPA 580, which is equipped with special probes. The principle of its operation consists in sucking in the skin using negative pressure generated by the device (450 mbar) into a 2 mm aperture of the probe for 2 seconds. After this time, the skin is released from the aperture, and after a relaxation time of 2 seconds it is sucked in again. Measurements were made at 10 facial sites: above the corner of the left eye (ELT), above the corner of the right eye (ERT), below the corner of the left eye (ELB), below the corner of the right eye (ERB), on the cheeks (left cheek – CL, right cheek – CR), above the left corner of the mouth (LLT), above the right corner of the mouth (LRT), below the left corner of the mouth (LLB), and below the right corner of the mouth (LRB). The measurement sites are shown in Figure 1.

The patients were familiarized with the examination procedure and the measurement sites on both sides of the face: above and below the outer corner of the eye, on the cheek, and above and below the corner of the mouth. Before each test, the patient’s face was wiped with micellar water and subjected to a 20-minute adaptation to ambient conditions. The tests were carried out in a room with a constant temperature of 21°C and air humidity in the range of 40%-60%. Three measurements were taken at the designated sites, each in a slightly different place to prevent skin fatigue. The order of measurements was the same in all the patients. First, the left side of the face was tested in the following order: above the corner of the eye, below the corner of the eye, on the cheek, above the corner of the mouth, and below the corner of the mouth. The measurements on the right side of the face followed the same pattern.

Based on the mean values of 3 measurements taken at each site, curves were obtained that made it possible to evaluate parameters R0, R2, R5, R7, R8, and R9. The R0 parameter assesses skin firmness as it represents the skin’s reaction to the applied force. The R0 parameter can be explained as a penetration which immediately after suction. Parameters R2, R5, and R7 relate to
skin elasticity—the closer the value is to 1 (100%) the more elastic the skin. Parameters R2, R5, and R7 can be explained based on curve (Figure 2). The R2 parameter can be defined as a ratio of complete relaxation and penetration immediately after suction. Next parameter, which define skin elasticity, is R5. The R2 parameter can be defined as a ratio of elastic part of the suction phase and immediate recovery during relaxation phase. Last parameter which define skin elasticity is R7. The R7 parameter can be defined as a ratio of elastic part of the suction phase and maximum penetration immediately after suction. The R8 parameter represents the skin's ability to return to its original state (the result is given in mm). Based on the curve (Figure 2), it can be read as $U_a$ that means complete relaxation of the skin after first suction. The R9 parameter relates to the fatigue effect on the skin after being repeatedly sucking in: the lower its value, the lower the fatigue effect. The R9 parameter can be defined as a difference between R3 parameter and R0 parameter that means the difference between last and first maximum amplitude. The sample curve shown below, and obtained as a result of the measurements performed with the Cutometer probe, graphically explains the measurement method (Figure 2).

Statistical analysis was performed using STATISTICA 13.1 software. The first step was to check the normality of distribution using the Shapiro-Wilk test as well as the Levene and Brown-Forsythe tests. When homogeneity of variance was established, Student's $t$ test was performed; in the absence of homogeneity of variance, Welch's $t$ test was carried out, and when the distribution showed no characteristics of normal distribution, the Mann-Whitney $U$ test was used. All the tests were performed at a significance level of 0.05. A correlation test was also done, which examined correlations between age and the individual parameters that were analyzed. The normality of distribution for age was checked using the Shapiro-Wilk test, followed by Spearman's non-parametric test.

3 | RESULTS

Using the Cutometer probe, results were obtained for the following parameters: R0, R2, R5, R7, R8, and R9. The values of the R0 parameter for all the measurement sites are presented in Figure 3. Statistical analysis of the R0 parameter is presented in the Table 1.

In the analysis of the R0 parameter, no statistically significant differences were observed between the left and right sides of the face either within each age group or when comparing the value of this parameter between the age groups.

The results of measurements for the R2 parameter are presented in Figure 4 and statistical analysis are shown in Table 2.

In the case of parameter R2, statistically significant differences were observed for three measurement sites around the eyes when comparing the two age groups.
Additionally, statistically significant correlations were obtained for eight measurement sites around the eyes and the lips, and on the cheek.

The results of measurements for the R5 parameter are shown in Figure 5.

Statistical analysis for the R5 parameter are shown in Table 3. In the case of parameter R5, statistically significant differences were observed for two measurement sites around the eyes when comparing the two age groups. The results of measurements and statistical analysis for the R7 parameter are shown in Figure 6 and Table 4. In the case of parameter R7, statistically significant differences were observed for five measurement sites around the eyes and the lips when comparing the two age groups. Additionally, statistically significant correlations were obtained for all the measurement sites.

The results of measurements for the R8 parameter are shown in Figure 7. In the case of parameter R8, statistically significant differences were observed for four measurement sites around the eyes and the lips when comparing the two age groups (Table 5). The results of measurements and statistical analysis for the R9 parameter are shown in Figure 8 and Table 6. In the case of parameter R9, statistically significant differences were observed for two measurement sites around the eyes and on the cheek when comparing the two age groups.

The values of the R7 parameter indicate that skin elasticity, and an ability to return to its original state around the eyes, on the cheeks and around the lips, is greater in the 25-40 age group.

4 | DISCUSSION

Maintaining proper medical records is a legal obligation for every physician. Instrumental assessment of skin quality parameters,
being an objective method, is an important component of a patient’s examination. Applying it in everyday practice makes it possible to objectively evaluate the effects of the administered treatment from the perspective of both the physician and the patient.

Measurements of facial skin elasticity on the cheeks were performed by Ryu et al in a group of 96 healthy Korean women in the 20-75 age group. The results showed a significant negative correlation for parameters R2 (−0.612), R5 (−0.401), R7 (−0.712), and R8 (−0.261). In the study presented in this paper, a significant negative correlation was observed on the cheeks for parameters R2 (−0.261) and R7 (−0.285), although parameters R5 and R8 also showed a negative correlation. Interpretation of the findings is hindered by the fact that different racial groups were included in the studies; however, it should be emphasized that a result indicating a smaller loss of skin elasticity with age was observed in this study. The R7 parameter was indicated by Ryu et al as the most significant when measuring facial skin elasticity. This is consistent with both the research conducted by Ohshima et al and the research conducted by the authors of this paper.

Ohshima et al performed measurements using a Cutometer Dual MPA 580 on the left cheek laterally from the naso-labial fold in a group of 32 healthy Japanese women (age range 29-55 years, mean age 42.3 years). The tests showed significant negative correlations between skin elasticity and age for the R2 (−0.509), R5 (−0.439), R7 (−0.510), and R8 (−0.603) parameters. A significant negative correlation for the left cheek was also obtained in the research presented here for parameters R2 (−0.261) and R7 (−0.285). In our tests, R7 was the only parameter showing a significant negative correlation for the measurement site on the left cheek (−0.285), as well as for all the other measurement sites, which confirms the results obtained by Ohshima et al, although the result also indicates a smaller loss of skin elasticity with age.

In a study by Cameli et al, the facial skin of twelve female patients aged 45-65 who had undergone esthetic medicine treatment...
with platelet-rich plasma was subjected to instrumental analysis. Skin elasticity (parameter R5) was assessed with a Cutometer MPA 580 before and one month after the treatment. In all cases, an improvement in the value of parameter R5 from an initial value of 0.125 to a value of 0.225 was observed.\textsuperscript{13} In this paper, parameters R2, R5, and R7 were used to assess the elasticity of facial skin. The results obtained for the R5 parameter in the 40-55 group ranged between 0.53 ± 0.25 and 0.8 ± 0.6. The discrepancy between the results recorded for the R5 parameter by Cameli et al and those obtained in our research, which suggests a considerable diversity of skin elasticity in this age bracket.

Kuering et al performed measurements of skin mechanical properties. Measurements were made on group of 120 volunteers, age range (24.7 ± 2.6) years. Measurements were taken using a Cutometer Dual MPA 580. Five regions of the skin were measured (cheek, neck, cleavage, forearm and hand). R2, R5, R7, and R8 parameters were analyzed. Analysis showed significant negative correlations between skin elasticity and age for all analyzed parameters, for the R0 (−0.446), R2 (−0.516), R5 (−0.276), R7 (−0.475), and R8 (−0.554), for cheek.\textsuperscript{14} In our study, significance negative correlation was presented, for both, left and right cheek for parameters R2 (left (−0.261) and right (−0.241)) and R7 (left (−0.285) and right (−0.274)). A negative correlation for left cheek was observed for R0 parameter (−0.096). Negative correlation was observed for both, left and right cheek, for R5 parameter (left (−0.171) and right (−0.151)), and R8 parameter (left (−0.231) and right (−0.134)).

In a study by Luebberding et al, measurements were made for four regions of the skin (cheek, neck, forearm, and hand), 300 healthy

**TABLE 3** Statistical analysis of the R5 parameter

| R5 | The P value, comparison of two age groups | The P value, comparison of sides | Correlation coefficient between the analyzed parameter and age (all patients) |
|----|------------------------------------------|---------------------------------|------------------------------------------------------------------|
|    | 25-40 | >40-55 | R   | P    |
| ELT | 0.007<sup>a</sup> | 0.651 | 0.681 | −0.223 | .060 |
| ERT | 0.048<sup>a</sup> | 0.648 | 0.838 | −0.032 | .788 |
| ELB | 0.462 | 0.648 | 0.838 | −0.208 | .085 |
| ERB | 0.176 | 0.434 | 0.600 | −0.171 | .161 |
| CL  | 0.625 | 0.434 | 0.600 | −0.171 | .161 |
| CR  | 0.510 | 0.561 | 0.778 | −0.121 | .316 |
| LLT | 0.741 | 0.561 | 0.778 | −0.136 | .273 |
| LRT | 0.900 | 0.561 | 0.778 | −0.136 | .273 |
| LLB | 0.136 | 0.600 | 0.508 | −0.268<sup>b</sup> | .025<sup>b</sup> |
| LRB | 0.157 | 0.600 | 0.508 | −0.258<sup>b</sup> | .029<sup>b</sup> |

<sup>a</sup>Statistically significant difference.
<sup>b</sup>Statistically significant correlation.
Caucasian men and women took part in research (150 male and 150 female), age range (20-74) years and the mean age for women was (44 ± 16) years. The aim of the study was to evaluate the correlation between skin elasticity and age in the all measured regions (cheek, neck, forearm, and hand). The significant negative correlation for all analyzed parameters and patients age: R0 (−0.526), R2 (−0.782), R5 (−0.604), R7 (−0.787), and R8 (−0.645) were found.

In our study, significant negative correlation can be also observed for some regions of facial skin (for R0 parameter, for RLT (−0.302), R2 parameter for all areas, except LLT and LRT, R5 parameter for LLB and LRB, R7 parameter for all regions of facial skin, and for R8 parameter for ELT (−0.244), LRT (−0.315), LLB (−0.272), and LRB (−0.244).

In the analysis of the R2 parameter, which describes skin elasticity, statistically significant correlations were found between skin elasticity and age at ELT, ERT, ELB, ERB, CL, CR, LLB, and LRB measurement sites. This suggests that the aging process affects the entire face at the same time. The R7 parameter suggest that skin elasticity, and an ability to return to its original shape around the eyes, on the cheeks and around the lips, is greater in younger patients. A search of the PubMed online database did not render any original publications regarding the sequence of facial aging. Thus, it is impossible to compare the results obtained in this study with the observations of other researchers.

In the evaluation of skin firmness (described by the R0 parameter), no statistically significant differences were observed between the sides of the face within each age group or when comparing this parameter between the two age groups. Skin firmness is therefore a constant parameter, independent of age.

Instrumental analysis makes it possible to predict the occurrence of complications and their severity as well as the effectiveness of treatments aimed at alleviating them, which was pointed out by Grippaudo et al. In their study conducted on a group of 26 patients who experienced complications connected after lip augmentation with hyaluronic acid, they used ultrasonography and MRI with

**TABLE 4** Statistical analysis of the R7 parameter

|          | The P value, comparison of two age groups | The P value, comparison of sides | Correlation coefficient between the analyzed parameter and age (all patients) |
|----------|------------------------------------------|---------------------------------|--------------------------------------------------------------------------------|
|          | 25-40                                    | >40-55                          | R                               | P                        |
| ELT      | 0.0000066<sup>a</sup>                    | 0.981                           | 0.175                           | −0.516<sup>b</sup> | .000<sup>b</sup>     |
| ERT      | 0.002<sup>a</sup>                        |                                 |                                 | −0.400<sup>b</sup> | .001<sup>b</sup>     |
| ELB      | 0.017<sup>a</sup>                        | 0.503                           | 0.589                           | −0.280<sup>b</sup> | .017<sup>b</sup>     |
| ERB      | 0.003<sup>a</sup>                        |                                 |                                 | −0.391<sup>b</sup> | .001<sup>b</sup>     |
| CL       | 0.385                                    | 0.479                           | 0.949                           | −0.285<sup>b</sup> | .017<sup>b</sup>     |
| CR       | 0.096                                    |                                 |                                 | −0.274<sup>b</sup> | .022<sup>b</sup>     |
| LRT      | 0.175                                    | 0.729                           | 0.861                           | −0.254<sup>b</sup> | .032<sup>b</sup>     |
| LRT      | 0.564                                    |                                 |                                 | −0.252<sup>b</sup> | .039<sup>b</sup>     |
| LLB      | 0.075                                    | 0.881                           | 0.921                           | −0.376<sup>b</sup> | .001<sup>b</sup>     |
| LRB      | 0.019<sup>a</sup>                        |                                 |                                 | −0.415<sup>b</sup> | .000<sup>b</sup>     |

<sup>a</sup>Statistically significant difference.

<sup>b</sup>Statistically significant correlation.
The P value, comparison of two age groups

| Parameter | ELT | ERT | ELB | ERB | CL | CR | LTT | LRT | LLB | LRB |
|-----------|-----|-----|-----|-----|----|----|-----|-----|-----|-----|
| 25-40     | 0.091 | 0.774 | 0.741 | 0.470 | 0.440 | 0.889 | 0.247 | 0.569 | 0.287 | 0.249 |
| >40-55    | 0.530 | 0.138 | 0.669 | 0.233 | 0.763 | 0.134 | 0.355 | 0.214 | 0.486 | 0.244 |

**Correlation coefficient between the analyzed parameter and age (all patients)**

| Parameter | R   | P   |
|-----------|-----|-----|
| ELT       | 0.695 | 0.044 | 0.711 |
| ERT       | 0.133 | 0.117 | 0.330 |
| ELB       | 0.210 | 0.066 | 0.583 |
| ERB       | 0.006 | 0.106 | 0.383 |
| CL        | 0.699 | 0.058 | 0.637 |
| CR        | 0.011 | 0.219 | 0.068 |
| LTT       | 0.651 | 0.135 | 0.261 |
| LRT       | 0.183 | 0.113 | 0.364 |
| LLB       | 0.855 | 0.056 | 0.644 |
| LRB       | 0.514 | 0.043 | 0.720 |

*Statistically significant difference.

**Figure 8** R9 parameter results for both age groups (25-40 y, >40-55 y)

**Table 5** Statistical analysis of the R8 parameter

**Table 6** Statistical analysis of the R9 parameter
intravenous contrast. This made it possible to conduct an objective examination and to make a proper diagnosis through excluding the proliferative process.  However, it is unknown what the initial condition was before the application of hyaluronic acid.

A number of other instruments are also used for the instrumental examination of the skin. The Antera 3D device is a compact camera analyzing an area of skin measuring 5.6 x 5.6 cm, assessing its color, presence of chromophores (eg, melanin and hemoglobin), pores, skin protrusions and depressions, texture, and wrinkles. The test is independent of the ambient lighting conditions because the lens of the device is in direct contact with the surface being examined. The VISIA system is the most widely used device for instrumental skin analysis in the world. An area of skin 22 mm in diameter is evaluated. Three light sources are used for the test: standard incandescent, ultraviolet, and cross-polarized light. VISIA enables a quick diagnosis of the patient’s skin condition, including an assessment of the presence of spots, wrinkles, texture, pores, UV spots, brown spots, red areas, and porphyrins. Comparing the two systems, the ANTERA 3D is more sensitive in the assessment of wrinkles and pores associated with the aging process. Other instruments used for non-invasive skin examination include the Visioscan VC 98, Corneometer, and DermaScan-C. The Visioscan VC 98 is used to assess the surface of the skin (profilometry), analyzing its roughness, smoothness, scaliness, and wrinkles. The Corneometer measures the water content in the stratum corneum, while the DermaScan-C analyzes the skin’s morphology by assessing such quantitative parameters as thickness or permeability to ultrasound. However, no publications are available that show the condition of the skin before the start of esthetic medicine treatments in various age groups; hence, the results of the present research make a certain contribution to expanding this area of knowledge.

5 | CONCLUSIONS

The study of instrumental diagnosis of facial skin carried out for two groups of women aged 24–40 and 40–55 years permits to conclude that the aging process simultaneously affects the entire facial skin. The skin firmness described by the R0 parameter is constant, independent of age. Moreover, it was noticed that the skin elasticity, and an ability to return to its original shape around the eyes, on the cheeks and around the lips, is greater in younger patients.

ACKNOWLEDGMENTS

No financial support was sought, or was received, for the creation of this paper.

ETHICAL APPROVAL

The measurements were carried out with the consent of the bioethics commission and follows the tenets of the Declaration of Helsinki.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article. This is not an innovative method, but these are new measurements that have been made with the device.

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How to cite this article: Kawalkiewicz W, Matthews-Kozanecka M, Janus-Kubiak M, Kubisz L, Hojan-Jezierska D. Instrumental diagnosis of facial skin—A necessity or a pretreatment recommendation in esthetic medicine. J Cosmet Dermatol. 2021:20:875–883. https://doi.org/10.1111/jcd.13638