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ACOUSTIC ANISOTROPY OF FACE SKIN

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Abstract: Skin is the largest structural formation which is easily open to investigation. However, diagnostic importance of its characteristics (in particular, mechanical characteristics in different states taking into account the age and a local pathological process) has insufficiently studied. The use of undestructive and uninvasive methods of estimation of skin mechanical characteristics has great significance in medical science and practice. The article presents facts about mechanical skin characteristics by the acoustic method. This method allows measuring velocities of the sound diapason superficial waves. Face skin (forehead and cheeks) of women at different ages was investigated (20 ~ 60 years). Different skin acoustic anisotropy of the mentioned areas was revealed (difference in the values of velocities were measured in the mutually perpendicular directions). Forehead skin (central and side parts) has different properties. Cheeks skin anisotropy changes from top to bottom. Acoustic anisotropy age changes are shown, which prove the evidence that anisotropy smoothes with the age.

Key words: face skin, velocity of superficial waves, acoustic anisotropy, age changes

It is necessary to know initial characteristics of skin to estimate the influence of different factors on it, including therapeutic and surgical cosmetologic interference. For this purpose we investigated face skin with the acoustic method using acoustic analyser of tissue [1,2]. This method allows measuring the spreading velocity of superficial waves of the acoustic diapason (frequency is 5 - 6 kH). We selected 10 women at the age of 20 years and 14 women whose average age was 60. Each of them had normal correct face form without dermathologic diseases. Before acoustic investigation, we measured their blood pressure in reclining position at a period of time from 10 to 13 o'clock (before dinner). Then we registered spreading velocity of superficial waves V in forehead and cheeks skin in the mutually perpendicular directions [3]: along vertical axis (long axis) of a body - velocity V_y, along horizontal plane - velocity V_x. Having registered the velocities the acoustic anisotropy coefficient K was calculated ($K = V_y / V_x$). This coefficient was taken for positive (K_+) under condition $V_y > V_x$ and for negative (K_-) under condition $V_y < V_x$. Diagonal lines of scanning were chosen firstly in the field of cheeks (Fig. 1). According to the results of the investigation (variant 1) we decided to change the disposition of scanning lines on the cheek in order to find any appropriateness of spreading superficial waves in the field of cheeks. That is why we took the horizontal position of diagnostic lines (variant 2, Fig. 2). Results of acoustic scanning face skin allowed revealing some peculiarities of change in velocities of spreading superficial waves of the sound diapason in different parts of face skin.

Knowledge of morphological structure of investigated tissues and comparison of morphofunctional characteristics have important significance for their interpretation. So, the general information on structural peculiarities of forehead skin is as follows [7]. The superficial epidermis crests in the middle forehead part. There are 5 to 9 layers of cells in the malpighian stratum. The Granular stratum consists of 2 to 3 layers of big cells. There is a thin

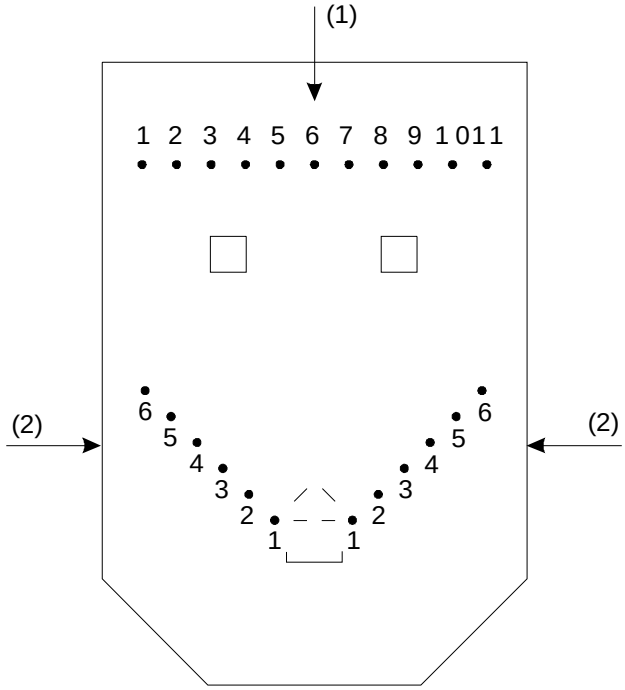

Fig. 1. Variant 1. The disposition of scanning lines on a face skin:
1 - line on forehead, 1.5 cm from eyebrows (11 points);
2 - line on cheeks, from corner of the mouth to the lobe of the ear (6 points).

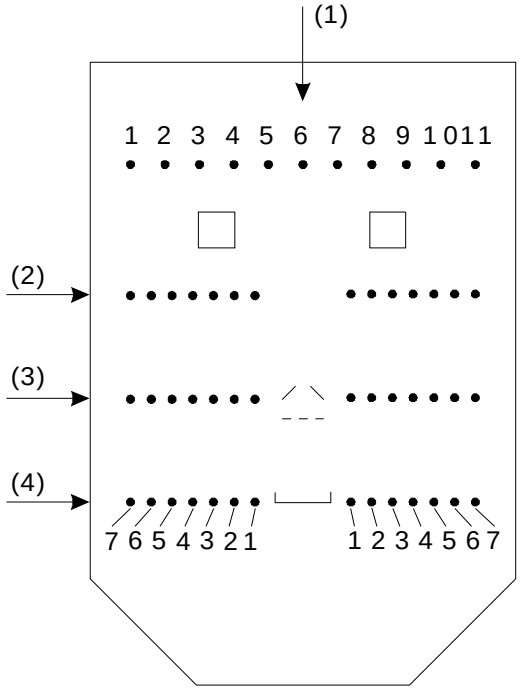

Fig. 2. Variant 2. The disposition of scanning lines on a face skin:
1 - line on forehead, 1.5 cm from eyebrows (11 points);
2 - the upper line of cheek (7 points);
3 - the medium line of the cheek (7 points);
4 - the bottom line of the cheek (7 points).

brilliant stratum well visible in the phase - contrast and luminescence microscopes. The horny stratum thickness constitutes the fourth part of the epidermis thickness. The derma is 7-8 times thicker than the epidermis and is built of collagenous fibers bundles of different thickness. The thickest bundles are in the depth of the net layer. There are thin bundles and a small cellular accumulation near the vessels. Elastic bundles form a dense net near epidermis. Thick, short, strongly twisted, vertically standing fibers are immediately under epidermis. There are not enough bundles in the depth of the derma, but their thickness is increased. Vast parts with a small number of bundles or almost without them are found between superficial and deep bundles. They are located near big capillary follicles and in the field of location of dermal vessels. The general direction of elastic bundles is across the frontal muscle (it is well found out in tangential areas). In separate observations it was found out that with age elastic bundles have tendency to form feltlike plexus. With age elastic bundles exhibit a tendency to join solid mass. These changes are constantly found at the age of 60 years.

Acoustic anisotropy findings present an important information on forehead skin peculiarities. Results of investigation for women aged 20 (by comparison of anisotropy coefficients K) are given in Table 2 and Fig. 3. It is established that there are points with positive and negative anisotropy. Points distribution submits to some appropriateness. Thus 1, 2, 3, 4 and 8, 9 10, 11 points (located to the right and to the left of the forehead line) have the least velocity in vertical direction (i.e. the horizontal velocity is more than the vertical velocity, $V_x > V_y$) because they are characterized by negative anisotropy. On the contrary, 5, 6, 7 points (situated in the middle part of the forehead line) have the greater velocity in the vertical direction (i.e. $V_y > V_x$), they are characterized by the positive anisotropy K_+ (Fig. 3). Forehead point 6 is characterized by greater value of the coefficient K (Fig. 4). It is evident that primary direction of superficial waves spreading in this point coincides with Y direction. This fact is in accordance with position of the natural Langer's lines [4 - 6] in the central

forehead part. The coefficient of anisotropy changes its sign in the range from 4 to 5 and from 7 to 8 points. 1, 2 and 11, 10 points are characterized by the maximum value of the coefficient K_{-}.

Negative anisotropy portion of 1, 2 and 11, 10 extreme points constitutes 90% - 100% of the considered cases, at 3, 4 and 9, 8 points - the negative anisotropy is in 60% - 90% of cases. In point 6, the positive anisotropy portion constitutes 90% of cases.

Results of investigation of changes in patients of another age group (middle age is 60 years) are presented in Table 3 and Fig. 5. Absolute values of coefficients decrease. The general tendency is kept in the above revealed appropriateness but scatter of velocities V_y and V_x for each scanning point are lesser (Fig. 6). While comparing the results in different age groups it can be established that with the age there occur changes in the investigated skin parts leading to acoustic anisotropy smoothing in forehead skin.

Table 1. Acoustic scanning (Fig. 2). V ± 2, m/s.

Position	n	$<V_y>$	$<V_x>$	$<V_y>/<V_x>-1$
right cheek line (2)	1	61.0	60.0	0.02
	2	61.0	60.0	0.02
	3	69.0	68.0	0.01
	4	62.0	65.0	-0.05
	5	73.0	71.0	0.03
	6	73.0	59.0	0.24
	7	67.0	80.0	-0.16
right cheek line (3)	1	59.0	60.0	-0.02
	2	59.0	60.0	-0.02
	3	63.0	66.0	-0.05
	4	64.0	64.0	0.00
	5	69.0	64.0	0.08
	6	67.0	66.0	0.02
	7	87.0	50.0	0.74
right cheek line (4)	1			
	2	53.0	67.0	-0.21
	3	53.0	67.0	-0.21
	4	64.0	68.0	-0.06
	5	61.0	62.0	-0.02
	6	73.0	76.0	-0.04
	7	55.0	50.0	0.10
right cheek line (1)	1	73.0	92.0	-0.21
	2	71.0	90.0	-0.21
	3	71.0	73.0	-0.03
	4	80.0	80.0	0.00
	5	79.0	86.0	-0.08
	6	78.0	74.0	0.05
	7	80.0	86.0	-0.07
	8	82.0	93.0	-0.12
	9	86.0	81.0	0.06
	10	99.0	110.0	-0.10
	11	95.0	109.0	-0.13

Position	n	$<V_y>$	$<V_x>$	$<V_y>/<V_x>-1$
left cheek line (2)	1	42.0	54.0	-0.22
	2	42.0	54.0	-0.22
	3	69.0	67.0	0.03
	4	76.0	75.0	0.01
	5	72.0	68.0	0.06
	6	90.0	57.0	0.58
	7	69.0	60.0	0.15
left cheek line (3)	1	58.0	44.0	0.32
	2	58.0	44.0	0.32
	3	63.0	72.0	-0.13
	4	68.0	64.0	0.06
	5	66.0	64.0	0.03
	6	68.0	65.0	0.05
	7	65.0	65.0	0.00
left cheek line (4)	1	44.0	67.0	-0.34
	2	44.0	67.0	-0.34
	3	49.0	64.0	-0.23
	4	55.0	65.0	-0.15
	5	68.0	70.0	-0.03
	6	67.0	58.0	0.16
	7	68.0	52.0	0.31

Table 2. The value of anisotropy coefficients in a forehead skin at 11 points (age – 20).

n	№1	№2	№3	№4	№5	№6	№7	№8	№9	№10	<*K*>	K_-, %	K_+, %
1	-0.35	-0.19	-0.04	-0.39	-0.21	-0.39	-0.26	0.08	-0.38	-0.20	-0.23	90	10
2	-0.20	-0.28	-0.27	-0.21	-0.21	-0.16	-0.10	-0.14	-0.25	-0.19	-0.20	100	0
3	0.08	-0.22	-0.16	-0.15	-0.13	-0.13	-0.05	-0.23	-0.15	-0.04	-0.11	90	10
4	-0.16	-0.15	0.05	-0.04	0.00	0.47	-0.10	-0.45	-0.06	-0.05	-0.05	70	30
5	-0.28	0.06	0.13	-0.01	-0.08	0.03	0.24	0.09	0.03	0.04	0.02	30	70
6	0.11	0.27	0.30	0.25	0.05	-0.21	0.21	0.24	0.35	0.25	0.18	10	90
7	0.23	-0.01	0.13	0.08	-0.07	0.07	0.27	-0.04	-0.04	-0.03	0.06	50	50
8	0.07	0.13	0.05	-0.08	-0.12	0.06	-0.14	-0.29	-0.04	-0.06	-0.04	60	40
9	0.10	-0.23	-0.43	0.16	0.06	-0.20	-0.07	0.11	-0.19	-0.07	-0.08	60	40
10	-0.22	-0.19	-0.35	-0.13	-0.10	-0.15	-0.18	-0.34	-0.30	-0.25	-0.22	100	0
11	-0.28	-0.20	-0.32	-0.14	-0.13	-0.29	-0.03	-0.07	-0.12	-0.20	-0.18	100	0

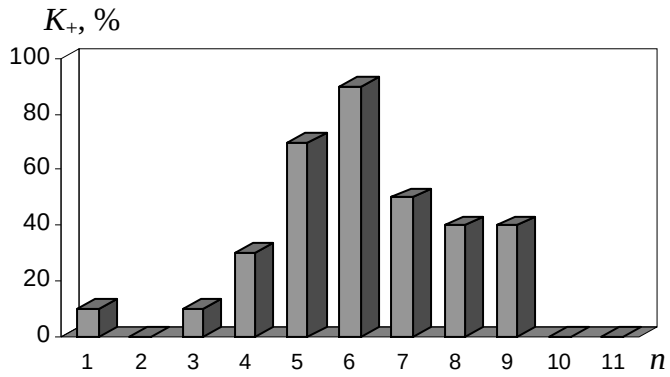

Fig. 3. The graphical display of the positive acoustic anisotropy coefficient in a forehead skin (age – 20).

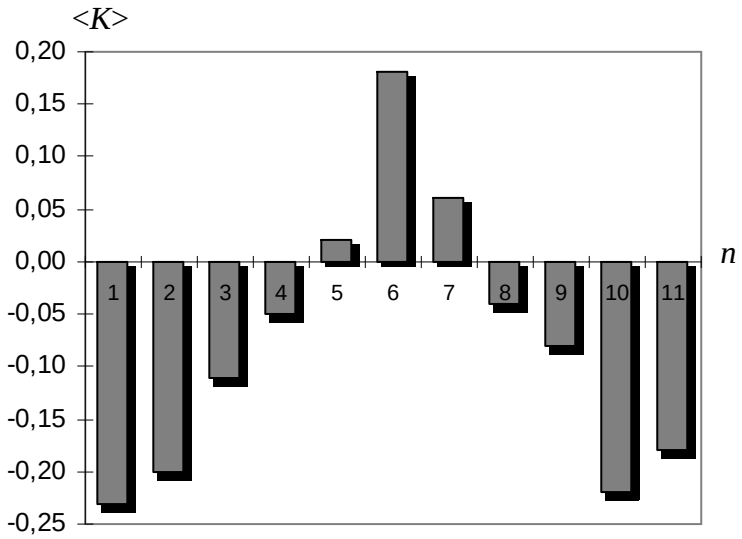

Fig. 4. The values of the acoustic anisotropy coefficient in a forehead skin (age – 20).

Table 3. The value of anisotropy coefficients in a forehead skin at 11 points (age – 60).

Position	*n*	*N*														<K>	K_-, %	K_+, %
		1	2	3	4	5	6	7	8	9	10	11	12	13	14			
forehead line (1)	1	0.01	0.05	-0.17	0.00	-0.09	-0.11	-0.34	0.12	0.08	0.05	0.06	-0.08	-0.02	0.12	-0.02	43	57
	2	0.03	0.00	-0.05	0.06	-0.08	-0.18	-0.47	0.00	0.06	0.07	0.04	-0.15	-0.03	0.05	-0.05	50	50
	3	-0.15	0.02	-0.24	0.04	-0.12	-0.14	-0.10	-0.15	0.00	0.05	-0.23	-0.03	-0.13	-0.13	-0.09	71	29
	4	-0.02	-0.18	-0.04	0.13	-0.10	-0.11	-0.15	0.03	-0.08	0.03	0.07	-0.03	-0.24	0.03	-0.05	64	36
	5	-0.12	0.07	-0.03	-0.12	0.00	-0.21	0.14	0.24	0.01	0.26	-0.03	0.06	0.10	0.06	0.03	36	64
	6	0.14	-0.13	-0.04	0.15	0.16	-0.06	0.11	0.37	-0.12	0.28	-0.07	0.01	-0.03	-0.13	0.05	50	50
	7	0.09	-0.04	0.06	0.06	0.00	-0.12	-0.03	0.11	0.17	0.17	-0.13	0.08	-0.06	0.06	0.03	36	64
	8	0.02	0.12	0.08	0.14	0.01	0.18	-0.25	-0.11	0.14	-0.25	-0.12	-0.16	-0.13	-0.01	-0.02	50	50
	9	0.17	0.07	0.05	-0.11	0.05	-0.15	-0.22	-0.17	0.04	-0.32	-0.10	-0.16	0.02	0.06	-0.06	50	50
	10	-0.05	0.06	0.27	-0.06	0.01	-0.19	-0.28	-0.27	0.08	0.08	0.00	-0.07	-0.17	0.03	-0.04	50	50
	11	-0.06	-0.02	0.14	0.05	0.04	-0.09	-0.13	0.34	0.07	0.11	0.04	0.00	-0.16	0.15	0.03	36	64

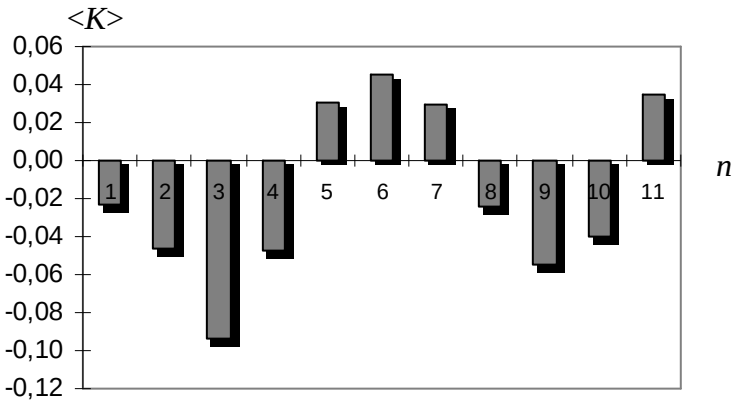

Fig. 5. The values of the acoustic anisotropy coefficient in a forehead skin (age – 60).

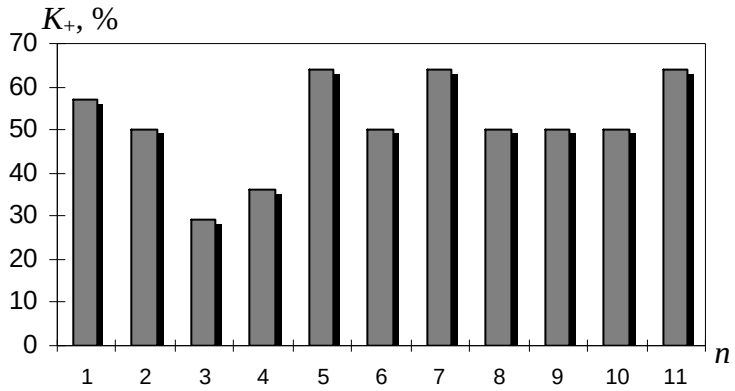

Fig. 6. The graphical display of the positive acoustic anisotropy coefficient in a forehead skin (age - 60).

One confirmation of this fact is the finding [7] which shows that regulated bundles position in the middle forehead part is transformed with age into feltlike plexus. Cheek skin has its own morphological peculiarities. It is covered by the epidermis of an uneven thickness forming broad superficial crests near hear follicles. There are 5 to 7 layers of cells in the malpighian stratum. The granular stratum consists of two layers of the flattest cells. The brilliant stratum is very thin. The horny stratum is thin (the fifth part of the whole epidermis thickness) and compact; it slightly thickens in hair follicles and sweat pores. The derma forms only a few papillae and contains moderate number of polysaccaride matters. The top part of the net stratum is built of thin fibers of connective tissue. There are thick bundles of

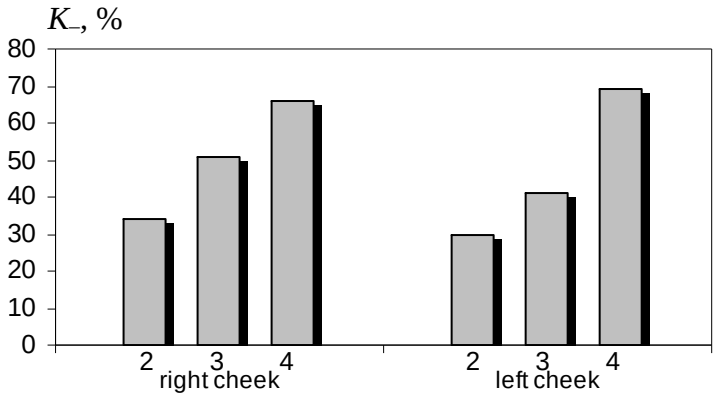

Fig. 7. The percentage of points with the negative acoustic anisotropy coefficient in skin of cheeks (age - 20).

collagenous fibers in the depth of the net stratum. There are many blood vessels. The great cells accumulations are situated around vessels. Elastic fibers form a dense plexus, short twist fibers come to the basal cells. There is dense arrangement of thin fibers in the net stratum. Feltlike plexus appears with age among thick fibers. There are only a few elastic fibers in the middle and in the depth of the net stratum. Sebaceous glands and roots of hair are surrounded with dense Mastic net; its thickness increases with age. Sweat pores are in small number. Cheek skin is very rich in unstriated muscles. Hypodermic adipose layers consist of big lobules, which are situated in several tiers.

The comparison of acoustic cheeks skin characteristics was made by virtue of three horizontal scanning lines (Fig. 2). Values of anisotropy coefficients of cheeks skin for women aged 20 at the different points became apparent in the form of positive or negative acoustic anisotropy *K* (Fig. 7). Results of acoustic scanning for another group of patients (average age is 60 years) did not expose anisotropy. So we can draw a conclusion that acoustic anisotropy of cheeks smoothes with age.

Acoustic method allows to find some peculiarities of mechanical face skin characteristics, i.e. existence of forehead and cheeks skin anisotropy which is notable for the different age groups. Subsequent determination of these peculiarities demands more deep study and gives a perspective of acoustic test for estimation of effectiveness of different factors influence on the skin to prevent its age changes.

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АКУСТИЧЕСКАЯ АНИЗОТРОПИЯ КОЖИ ЛИЦА

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Кожа является самым крупным органом тела человека, легко доступным для обследования. Однако диагностическая значимость свойств кожи, в частности, механических свойств изучена недостаточно. Поэтому использование неразрушающих неинвазивных способов оценки механических свойств кожи имеет большую актуальность в медицинской диагностике. В статье приводятся данные о механических свойствах кожи, оцениваемых посредством акустического метода. Данный метод позволяет измерять скорость распространения поверхностных волн (возмущений) звукового диапазона. Исследована кожа на лице в области лба и щек у женщин различного возраста (20 и 60 лет). Выявлена различная акустическая анизотропия кожи указанных участков (различие в значениях скоростей, измеренных во взаимно перпендикулярных направлениях). В коже лба акустическая анизотропия центральной и боковых частей противоположна. В коже щек анизотропия изменяется сверху вниз. Показаны возрастные изменения акустической анизотропии, которые свидетельствуют о том, что с возрастом акустическая анизотропия нивелируется. Библ. 7.

Ключевые слова: кожа лица, скорость поверхностных волн, акустическая анизотропия, возрастные изменения

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