JEADV ISSN 1468-3083

ORIGINAL ARTICLE

Cellulite and skin ageing: is there any interaction?

JP Ortonne†, M Zartarian‡, M Verschoore*‡, C Queille-Roussel§, L Duteil§

† Dermatology Department, Archet Hospital, Nice, France
‡ L'Oréal Recherche, Asnières, France
§ CPCAD, Archet Hospital, Nice, France

Keywords
cellulite, dermal echogenicity, high frequency ultrasound imaging, skin ageing, skin mechanical properties

*Corresponding author, L'Oréal Recherche, 25–29 Qual Aulagnier, 92665 Asnières cedex, France, tel. +33 1 47 56 87 97; fax +33 1 47 56 76 30; E-mail: mverschoore@rd.loreal.com

Received: 8 August 2007,
accepted 22 November 2007

DOI: 10.1111/j.1468-3083.2007.02570.x

Abstract

Objective This study aimed to identify the characteristics of cellulite in women of different age and to appreciate whether cellulite could interfere with skin ageing or not.

Methods 94 healthy female, divided into three age groups (21–30yrs; 31–40yrs; 51–60yrs) and two grade groups of cellulite (grade 2; grade 0 or control group) were investigated using non invasive techniques. The "orange peel appearance" was quantified by measuring the shadowed surfaces under low angle light. The biomechanichal properties were measured (extensibility-retractability-elasticity). The thicknesses of the skin structures were also evaluated using ultrasound. Echogenicity of the dermis was recorded and dermis density determined in two bands (superficial and low dermis).

Results In grade 2, the shadowed surfaces are significantly different according to age; i.e. smaller and more numerous after age of 30; the total skin thickness including hypodermis is increased of about 30% irrespective to age, compared to control group.

The biomechanical properties of the skin are significantly modified as age increases without any grade effect. In grade 2, retractability and elasticity parameters are altered from age 30 whilst only from age 50 in the control group. Echogenicities of the superficial and deep dermis also decrease from age 30 and become significantly lower than the ones of grade 0.

Conclusion Population with cellulite presents earlier skin ageing characteristics than control population. Two sub-populations may exist: the under 30 age with large dimpled surfaces, normal biomechanical and density properties; and the over 30 age with smaller and numerous dimpled surfaces and already altered dermis properties. This premature skin ageing should be prevented accordingly.

Introduction

Cellulite is a condition that affects thousands of women of any age worldwide.

Characterized by its 'orange peel' appearance of the skin surface, located mainly on the external and back sides of the thighs, on the buttocks or even on the abdomen, cellulite falls into the aesthetic field and is not considered as a disease. However, complaints of the women are real, and the demand for care is very high, especially when summer is coming. Surgical solution such as subcision[1] has already been successfully developed to answer to their need and to treat this characteristic aspect of 'orange peel'. Around 85% of women, whether they are slim, fat or obese are concerned by cellulite as overweight is only aggravating the phenomenon but not initiating it. Some authors even consider cellulite as a secondary sexual nature linked to the female sex.

The diagnosis of cellulite is essentially clinical, and the severity of the affection most often refers to the Nurnberger[2] classification whose scale is quite imprecise. There is no consensus on the physiopathology of cellulite;[3–5] moreover, the absence of standardization of objective evaluation criteria, when different treatments[6,7] are used, also constitutes a factor limiting awareness of the condition and of its reactivity.

At the present time, it has been much noted that, whatever the primum movens, cellulite links three elements: adipocyte hypertrophy, microcirculation disorders and venous stasis, connective tissue abnormalities, even fibrosis. These last three factors combine and change with time,[8] and age clearly modifies the clinical appearance of cellulite.

This study aimed not only to identify the characteristics of cellulite in women of different ages using non-invasive investigation techniques but also to appreciate those of skin ageing whether cellulite is present or not. Is cellulite able to have any interaction with skin ageing?

Population, material and methods

Population

The study involved 94 healthy female volunteers, with gynoid morphotype, clearly informed (signature of the informed consent form) aged between 20 and 60 years and divided into three age groups (21–30 years, 31–40 years and 51–60 years) presenting either a cellulite of the thighs –(grade 2) according to the Nurnberger classification ('orange peel' appearance spontaneously visible and disappearing in layered position) or no cellulite –(grade 0; no any 'orange peel' appearance spontaneously visible), these latter representing the control group.

Each age group included at least 20 grade 2 subjects and 10 grade 0 subjects. The demographic characteristics of the population are summarized by age group and cellulite grade in Table 1.

Table 1 Study population (mean ± SD)

		[21–30 years]	[31–40 years]	[51–60 years]
Number of subjects	*Grade 0*	10	10	10
	Grade 2	20	21	23
Age (years)	*Grade 0*	26.8 ± 4.7	35.5 ± 3.0	57.0 ± 3.3
	Grade 2	25.3 ± 2.7	36.2 ± 2.8	55.9 ± 2.9
Weight (kg)	*Grade 0*	50.4 ± 4.5	59.8 ± 6.9	56.9 ± 6.5
	Grade 2	62.0 ± 7.5	61.9 ± 4.8	62.3 ± 7.0
BMI (kg/m^2)	*Grade 0*	19.3 ± 1.3	21.3 ± 2.1	22.5 ± 1.8
	Grade 2	23.6 ± 2.4	23.2 ± 2.3	24.1 ± 1.6

Materials and methods

All steps were achieved in one session for each subject on a test area of approximately 8 × 8 cm chosen in the middle of the external part of one of the two thighs.

Quantification of the «orange peel» appearance

Skin relief of the area was assessed by macrophotography achieved in standing position, the axis of the camera being perpendicular to the plane of the surface to be photographed, in low-angled light to produce the most shadow. The device used was a Canon EOS 20D (8.2 million pixels) fitted with a Canon compact-macro 50 mm F 2.5 macro camera. The device was mounted onto a Canfield Scientific optical bench, modified to take photographs of the thigh with subjects in a standardized position. The low-angled lighting was obtained using a collimated low-angled light producing a vertical patch beam directed laterally with very low angle to the area to be photographed. Achieved in black and white, the photographs were analysed by grey level processing and the shadow index determined in relation to the shadowed surface (hollows and bumps due to cellulite) over the total surface. A count of these 'shadowed surfaces' was also carried out for grade 2 subjects.

Measurement of the biomechanical properties of the skin

Each biomechanical measurement was carried out on the subject in a semi-stretched out rest position with legs in horizontal position.

Measurements with the Dermal Torque Meter® whose principle[9] is based on the Twistometer[10] contributed to the determination of the viscoelastic properties of the skin. The Dermal Torque Meter is based on a central disk (20 mm in diameter) surrounded by a concentric disk and the gap between the two disks (the guard) is adjusted to 5 mm to measure the deep dermis. Four parameters are determined according to the torsion couple applied: U_e (extensibility index); U_v (viscoelasticity index); U_r (retractability index); U_r/U_e relationship (elasticity index). Five measurement cycles were achieved but only results regarding cycles 1 and 5 were kept for analysis.

The skin wrinkling index was observed using the Densiscore®[11] whose assessment is essentially based on the breadth of skin folds under compression. Made up of two rectangular parts (4 × 2 cm), fixed on the skin with double sided adhesives, and which can slide one towards the other by means of two lateral axes able to reduce the space between the two rectangles to 14 mm, the Densiscore® enables the wrinkling of the skin surface and the scoring of this 'wrinkling' from 0 to 5.

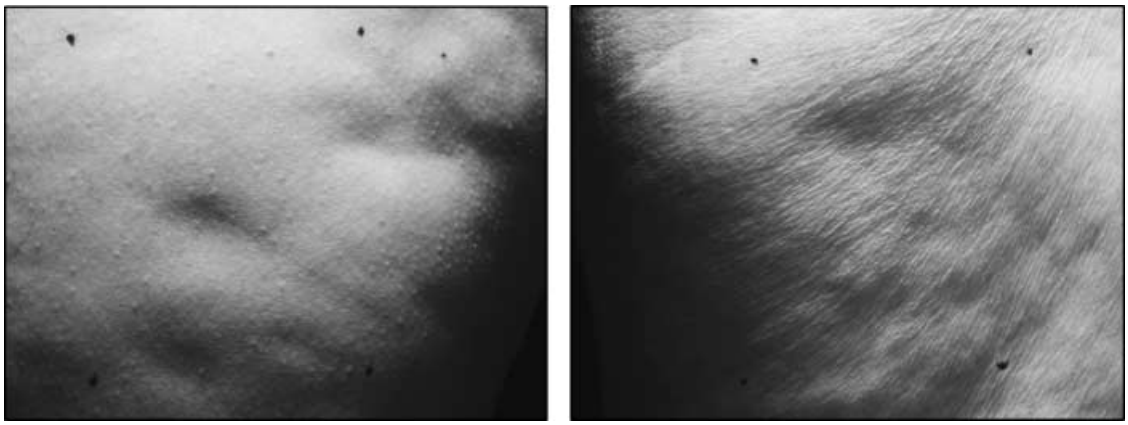

fig. 1 Standardized macro photographs on thigh (grade 2 cellulite/low-angle light) to the left (21–30 age group subject) and to the right (51–60 age group subject).

Measurements of the thickness of skin structures

A measurement of the skin fold thickness was performed using a Caliper gauge in one point of the test area.

A measurement of 'the epidermis and dermis' thickness was achieved using ultrasound with the help of a B scanner (Dermascan C, Cortex Technology, Hadsund, Danemark) fitted with a probe of 20 MHz. The intensity of the ultrasound echoes sent back was visualized in the form of a bi-dimensional colour image. This latter makes possible to dissociate the skin structures, according to the colour level corresponding to the echogenicity level and to measure the thickness of the skin (epidermis and dermis) in several areas (calculation of the mean thickness and measurement of the minimal thickness) as well as the length of the dermis–hypodermis interface. Three measurements were achieved on the test area and the average of the three values obtained for each parameter was retained for analysis.

Measurement of subcutaneous thickness: with the help of a B scanner (ALOCA type Alpha 10) fitted with a bar probe functioning at 10 MHz, five thickness measurements were achieved in real time on the test area, and the average of the five values was retained to determine the 'total skin thickness' including hypodermis.

Measurement of the echogenicity of the dermis

After acquiring and recording the ultrasound images (epidermis and dermis) from the B scanner, 20 MHz, those can be treated using a specific software (DERMAVISION 2D, Cortex Technology). This latter attributes a numerical scale of 0 to 255 to the amplitude values of the ultrasound echoes. The echogenicity of the skin was achieved on a surface band of the dermis of 250 μm in thickness without taking account of the echo entrance band (gel–skin interface) as well as that of a deep band of 250 μm also, located just above the dermis–hypodermis interface. In order to evaluate the density of the dermis, the number of intensity pixels included between 195 and 255 (high echogenicity range) of these two bands analysed was determined for each of the subjects.

Statistical analysis

The statistical analysis was achieved using SYSTAT software (version 11.0). Before any statistical processing, the normality of the variables was analysed with a Shapiro-Wilk test. In the case of normality, parametric tests were used (Student's test, variance analysis); in the case of abnormal distribution, non-parametric tests were used (Wilcoxon test, Kruskal–Wallis test).

Thus, for the variables with normal distribution, a variance analysis testing grade and age factors as well as grade × age interaction was carried out on each variable. In the case of the significance of the age factor, age groups were compared using the contrasts method. For variables with abnormal distribution, a Kruskal–Wallis test was carried out testing the age factor. In case of significance, the age categories were compared two by two with a Mann–Whitney test. An intragrade analysis was also carried out on each of the two populations (grade 0 and grade 2) by using the same tests to compare the age groups as those carried out on the total population (grade 0 and grade 2). The significance threshold in all cases was fixed at 5%.

Results

It is appropriate to observe that, in the study population (Table 1), the variance analysis reveals a sensitive age effect that increases the weight parameter ($P = 0.028$), but

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Table 2 Dermal Torque Meter® measurements – Descriptive statistics (mean ± SD) on cycles 1 and 5 and variance analyses

		Grade 0			Grade 2		
		21–30 years	**31–40 years**	**51–60 years**	**21–30 years**	**31–40 years**	**51–60 years**
Cycle 1	U_e	3.58 ± 0.82	3.76 ± 0.70	2.88 ± 0.64	3.74 ± 0.65	3.51 ± 0.74	3.27 ± 0.87
	U_r/U_e	0.53 ± 0.07	0.51 ± 0.08	0.51 ± 0.07	0.54 ± 0.09	0.49 ± 0.07	0.50 ± 0.07
Cycle 5	U_e	4.92 ± 1.08	5.24 ± 0.97	4.19 ± 0.68	5.22 ± 0.88	4.95 ± 0.92	4.93 ± 1.11
	U_r/U_e	0.38 ± 0.07	0.36 ± 0.07	0.33 ± 0.04	0.39 ± 0.07	0.34 ± 0.05	0.33 ± 0.05

	U_e		U_v		U_r		U_r/U_e	
Variance analyses	Cycle 1	Cycle 5	Cycle 1	Cycle 5	Cycle 1	Cycle 5	Cycle 1	Cycle 5
Age	$P = 0.0062$	$P = 0.07$	NS	NS	$P = 0.0007$	$P = 0.0008$	NS	$P = 0.003$
Grade	NS	NS	$P = 0.02$	NS	NS	NS	NS	NS
Age*grade	NS	NS	$P = 0.045$	NS	NS	NS	NS	NS

above all, an effect linked to the grade on the weight ($P < 0.001$). Grade 0 women, therefore, weigh less than grade 2; the difference is specifically marked in the 21 to 30 age range with a gap of 11.6 kg between grade 0 and grade 2. On the other hand, the grade 2 women have a not significantly different weight and BMI according to age group.

Analysis of the 'orange peel appearance'

Variance analysis relating to the shade index shows a significant effect of the grade ($P < 0.001$) without age effect with a percentage of respectively 25.72 ± 13.23 to 35.29 ± 13.50 and 30.34 ± 11.25 in grade 2 groups of 21–30, 31–40 and 51–60, whereas negligible values are noticed in grade 0. Moreover, the number of 'shadowed surfaces' (grade 2 only) is significantly different according to the age range: from 3.3 ± 1.8 in the 21–30 age group to 5.2 ± 2.3 and 5.2 ± 2.5 in the older groups. The age intergroup comparison underlines very clearly the two sub-groups of women with cellulite: those between 21 and 30 years and the older who present a sensitively different macro photographic appearance (fig. 1) including a greater number and smaller 'shadowed surfaces' (the total shaded surface being comparable).

Biomechanical properties of the skin

Dermal Torque Meter measurements

Variance analyses on cycles 1 and 5 (Table 2) show a significant effect linked to age on the following parameters: U_e (extensibility index; $P = 0.006$ cycle 1) and U_r (retractability index; $P = 0.0007$ cycles 1 and 5) and ratio U_r/U_e (elasticity index; $P = 0.0037$ cycle 5) without any difference for the U_v parameter (viscoelasticity index).

These different indices progressively decrease with age without any grade effect. However, the comparison of intragrade analyses shows an earlier significant difference between age groups in the grade 2 population. Although in the grade 0 population, U_e and U_r become significantly different (Table 3) from the age of 40 (21–30 vs. 31–40 = NS), there is an interage group significant difference from 30 years in the grade 2 population [21–30 vs. 31–40; pU_r = 0.043 (cycle 1) and 0.028 (cycle 5) and pU_r/U_e = 0.019 (cycle 5)].

Skin wrinkling index

The wrinkling index is not modified by cellulite: if there is a very significant age group effect ($P < 0.001$), there is no grade effect ($P = 0.859$). The change of the wrinkling index, which remains above all a surface measurement really representing skin ageing, appears from the age of 30 (Table 3) and increases with the years regardless the grade of cellulite (interage group comparisons: 21–30 vs. 31–40 and 21–30 vs. 51–60 and 31–40 vs. 51–60; $P < 0.001$).

Thickness of skin structures

Skin fold thickness

There is a very significant grade effect ($P < 0.001$) as regards the measurement of the thickness of the skin fold, grade 2 women having a mean skin fold of around 30% greater than that of the grade 0 population, independently of the age group. Moreover, in the grade 2 population,

Table 3 Results of the intra-grade analysis on grade 0 and grade 2 subjects

			Grade 0			Grade 2		
			'21–30 years' *versus* '31–40 years'	**'21–30 years' *versus* '51–60 years'**	**'31–40 years' *versus* '51–60 years'**	**'21–30 years' *versus* '31–40 years'**	**'21–30 years' *versus* '51–60 years'**	**'31–40 years' *versus* '51–60 years'**
Dermal Torque Meter measurements	Cycle 1	U_e		$P = 0.046$	$P = 0.009$			
		U_r		$P = 0.037$	$P = 0.010$	$P = 0.043$	$P = 0.02$	
		U_r/U_e						
	Cycle 5	U_e						
		U_r		$P = 0.050$	$P = 0.015$	$P = 0.028$	$P = 0.001$	
		U_r/U_e				$P = 0.019$	$P = 0.002$	
Skin wrinkling index			$P = 0.044$	$P < 0.001$	$P < 0.001$	$P = 0.001$	$P < 0.001$	$P < 0.001$
Ultrasound	20 MHz	Epidermis + dermis mean thickness						
		Interface dermis-hypodermis						
		Number of pixels				$P = 0.029$	$P = 0.008$	
	10 MHz	Mean total skin thickness						
Macro-photographs		Percentage of shadowed surface						
		Number of «shadowed surfaces»				$P = 0.002$	$P = 0.007$	
Skin fold thickness				$P = 0.003$				

this skin fold remains constant in the three age groups (from 3.33 cm ± 0.76 to 3.76 cm ± 0.96), whereas it tends to decrease in the grade 0 population with age (2.95 cm ± 0.42–2.56 cm ± 0.49 and 2.32 cm ± 0.41, respectively; comparison 21–30 year vs. 51–60 year: $P = 0.003$).

Dermis and epidermis thickness

No significant difference has been observed on skin ultrasound data (probe 20 MHz) as regards the mean thickness of the skin whose values remain stable (from 1.57 mm ± 0.20 up to 1.73 mm ± 0.10), whatever the age or the grade of cellulite is. However, there is a very significant difference according to grade ($P < 0.001$) for the minimum value of the skin thickness: in grade 2, the indentation of the hypodermis into the dermis induces a decrease of the minimal thickness (according to age groups, grade 0: from 1.30 mm ± 0.19 up to 1.46 mm ± 0.16 – grade 2: from 1.17 mm ± 0.20 up to 1.21 mm ± 0.20). There is no link with age for this variable.

A very significant difference ($P = 0.000$) according to grade is observed as regards the length of the dermis–hypodermis interface without any age effect nevertheless. The herniation of the hypodermis in the dermis, in the event of cellulite, is responsible for this increase of interface length (Table 4).

Table 4 Descriptive statistics (mean ± SD) and results of variance analysis on the ratio: length of the interface dermis/hypodermis/total length

	Descriptive statistics		
	21–30 years	**31–40 years**	**51–60 years**
Grade 0	1.06 ± 0.04	1.06 ± 0.04	1.08 ± 0.05
Grade 2	1.17 ± 0.06	1.17 ± 0.07	1.17 ± 0.07
Variance analysis			
Age effect		$P = 0.771$	
Grade effect		$P = 0.000$	
Age*grade effect		$P = 0.641$	

Total skin thickness

Total skin thickness including hypodermis measured using 10-MHz ultrasound probe shows a very significant grade effect ($P < 0.001$) without any age effect. This mean thickness, in grade 2, is close to 30 mm (30.29 ± 4.91 to 29.28 ± 6.61 and 27.26 ± 6.78 from younger to older age group, respectively) compared with about 22 mm in grade 0 (from 23.58 ± 4.71 to 19.86 ± 3.79 and 22.64 ± 5.28 according to age group respectively); that is around 30% thicker with slight variations according to age group.

Table 5 Descriptive statistics (mean ± SD) and results of the variance analysis on the number of pixels (195–255 range)

	Descriptive statistics			
	Band	**21–30 years**	**31–40 years**	**51–60 years**
Grade 0	High	1046 ± 420	1256 ± 547	1363 ± 1027
	Low	621 ± 776	779 ± 496	900 ± 706
Grade 2	High	1118 ± 447	898 ± 438	756 ± 342
	Low	547 ± 317	404 ± 258	474 ± 387
Variance analyses				
Age effect	$P = 0.879$			
Grade effect	$P < 0.001$			
Band effect	$P < 0.001$			

Echogenicity of the dermis

Determined by measuring the number of pixels of high echogenicity on two bands (superficial dermis and deep dermis), the echogenicity of the dermis (or density) proved to be significantly different according to grade ($P < 0.001$) and band ($P < 0.001$). The echogenicity is actually higher in the superficial band (high) than in the deep band (low) and it is lower in the grade 2 (Table 5). In addition, a very clear different evolution is observed according to grade: when the number of pixels (high and low) is relatively stable in grade 0 without any difference regarding the age group, there is in the grade 2, a decrease of echogenicity (high and low) that begins from the age of 30 and continues in time. This last characteristic significantly distinguishes the 21- to 30-year age group from the two other age groups in grade 2 population.

Discussion

This study underlines various clinical and structural skin characteristics in women with grade 2 cellulite, suggesting that cellulite has an impact on skin ageing.

Overweight and abnormal waist-to-hip ratio[12] are key points to prevent the apparition of cellulite. This study shows an increase of skin fold and total skin thickness (including hypodermis) of about 30% in grade 2 population irrespective of age. This corroborates the well documented[13] structural hypodermic hypertrophy present in case of cellulite, and which does not seem to change with age. The selection criteria of our population do not allow us to assess the predictive value of severe cellulite nature such as reported by L.K. Smalls.[14]

The characterization of the 'orange peel appearance' and particularly the study of the 'shadowed surfaces' allows to distinguish two subpopulations among women with cellulite: those of 21–30 years old, presenting large but less numerous dimpled surfaces, and those of more than 30 with smaller and more numerous dimpled surfaces. No study in the literature may support or invalidate this observation.

The biomechanical properties of the skin, either from the measurements with the Dermal Torque Meter® (extensibility – retractability – elasticity indices) or from those with Densiscore® (wrinkling index) are significantly modified with age. This reveals that the alterations of the superficial and deep dermis[11–15] are both correlated with age, but this must not completely eliminate the role played by cellulite. Indeed, this study strongly shows a premature alteration of the retractability and elasticity parameters in the grade 2 population in women aged from 30, whereas this latter is only observed in grade 0 population in women aged over 40.

Regarding dermis in case of cellulite,[2] many authors have already reported a thinner low dermis in female than in man, and a deep deformation of the dermis–hypodermis interface linked with the herniation of the hypertrophic adipocytes[13–16] into the dermis. Our study has allowed the observation, in case of cellulite, of an increased length of the dermis–hypodermis interface with a decreased minimal thickness of the 'epidermis and dermis' measured by 20-MHz ultrasound, without age effect. On the other hand, the mean 'epidermis-dermis' thickness is neither modified by age nor by grade.

These last data match with those mentioned in the literature,[17,18] which report no cutaneous atrophy before the age of 70. The first extensibility modifications are linked to a lack of moisturizing of the stratum corneum and to its rigidity, but not to the thickness of the dermis.[9]

Moreover, our results give evidence of a greater echogenicity of high range in the superficial dermis than in the deep dermis, irrespective of age group or grade of cellulite. This greater echogenicity was already reported by Batisse[11] on arm skin level, but only in young subjects. In older subjects, albeit less than 60 years old, the less echogenicity of the superficial dermis compared with the deep dermis could be linked to sun exposure,[19] which induces a degradation of collagen fibres. We could not observe this age effect on the investigated thigh area but only note a steady trend of a marked decrease in the high range level of echogenicity in the superficial dermis in the grade 2 population aged from 30 years. On the other hand, the choice of only analysing the high level pixels (range, 195–255) and not the whole pixel range in the band, in order to define 'an average', may be the reason for such differences. Our analysis method, very specifically, does not take into account the determination of low echogenicity levels and the characterization of the sub-epidermal low echogenic band (SLEB or SENEB) more or less disputed as regards its specificity and its photo-induced ageing marker sensitivity.[20,21]

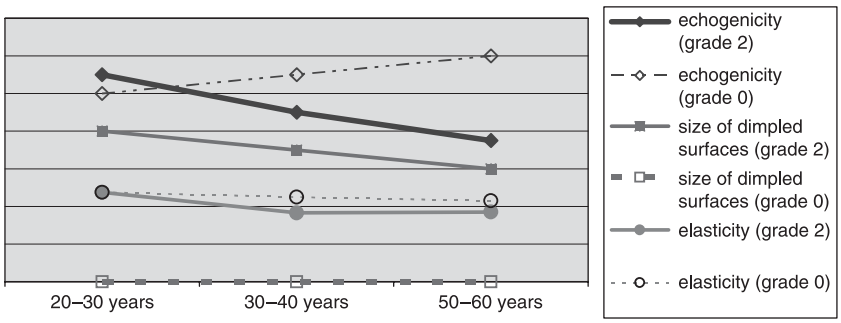

fig. 2 Schema of the evolution of three markers relative to cellulite/skin ageing, according to age and grade.

In the same way, low levels of deep echogenicity (DEB, dermal echogenic band) were reported to increase with age,[22] which our technique did not measure.

However, our results show a clear grade effect with a marked decreased echogenicity of the superficial and deep dermis in the grade 2 population: this hypodensity is reflected by the significant decrease of the number of 195 to 255 pixels in both bands compared with those observed in the grade 0 population, especially from age of 30. This degradation of the superficial and deep dermis, in the cellulite population over 30 of age, is accompanied by various biomechanical changes including the reduction of the elasticity index recorded by Dermal Torque Meter® (see fig. 2).

The observation of the different parameters of the study allows considering the existence of different populations according to grade. The population without cellulite presents characteristics linked with skin ageing that can be observed from 40 of age. On the other hand, the population with cellulite seems to present the same characteristics at an earlier age. In the latter population, there are thus two sub-populations: that of the under 30 age group that presents large dimpled surfaces with still normal biomechanical and echogenic skin properties and the over 30 age group with smaller and more numerous dimpled surfaces and whose dermal characteristics have already been affected by skin ageing. This feature, in addition to a lower minimal skin thickness, irrespective of age, compared with the population without cellulite must lead to the use of dermal trophics earlier than in the general population. Assuming that premature skin ageing is a cause or a consequence of cellulite, it is advisable to take this interaction into consideration, to prevent earlier skin ageing and implicitly fight against cellulite. These new data let appear interesting perspectives for the future.

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