32nd IFSCC Congress
"Where beauty, science and innovation meet"
London 19–22 September 2022

sederma

Characterisation of knee ageing by fringe projection,standardised pictures and elasticity measures

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INTRODUCTION

There is only a few research on ageing of the knee but it has been demonstrated that on this region, wrinkles increase and elasticity decreases with age [1]. Another study showed a correlation between observed laxity severity and age [2].

The laxity of the skin is caused by sagging of subcutaneous structures and, like wrinkles, is principally due to the loss of dermal extracellular matrix constituents, such as collagens and elastin. Moreover, aging promotes a low moisturisation of knees which are already drier than other part of the body due to a lowest sebum secretion. Weight changes, high BMI and sun exposures are also positively correlated with skin knees degradation [2].

Wrinkled and flaccid skin of knees are now becoming an important cosmetic concern for many people. There were mainly surgical options since years but recently noninvasive treatments aiming to tighten the skin were developed. Physical treatments are used to improve dermal strength and elasticity by remodeling the dermis with new collagen and elastin. This can be done by using targeted energy to penetrate dermis and form precise thermal coagulation points. Some devices are available with energy from a variety of sources including monopolar and bipolar radiofrequency, laser light sources, or microfocused ultrasound [3]. Moreover low-invasive treatment consists in injection of calcium hydroxyapatite to stimulate the synthesis of collagens and increase neovascularization [4].

In addition, several products exist and are safely used by the cosmetic industry to improve dermis and epidermis properties, such as plant extracts or small and well characterized peptides. Later are well known to trigger collagens and elastin synthesis or to reinforce epidermal barrier functions [5].

For evaluating treatments efficacy, or classify people, specific scales were done for laxity, cellulitis or wrinkles [6]. To our knowledge, only one study was focused on knees evaluation with metrological devices [1].

Our objective was to set up illustrative and quantitative methods allowing to show knees wrinkles changes thru ageing or, conversely, after treatments. For this, 2 methods based on 2D / 3D images were developed and 3 existing devices for skin visco-elasticity and density were tested on a panel of volunteers of different ages.

MATERIAL AND METHOD

Panel

30 female volunteers aged 21-71 y/o (mean 51 y/o) were recruited and represented 3 age groups (7 "young" < 40 y/o, 13 "middle" 41 to 60 y/o, and 10 "old" >60 y/o). Measures and acquisitions were done on the upper and middle part of right and left knees.

Photographic system

A photographic bench HeadScan V04 with a body module (Orion TechnoLab™) was used to set up the pictures system. The position of the body, and especially the pelvis and feet, is very important to have optimal and standardized pictures. In order to control both part of the body we developed a system to wedge the the volunteers and thus avoid any movement. Moreover, a measuring device was set up to specifically position the feet angles. Reproducibility of pictures over time was evaluated by comparing pictures taken at 30minutes interval.

Skin elasticity

Skin elasticity was measured using Cutometer® MPA580 (Courage + Khazaka) and ElastiMeter (Delfin technologies).
For measures with the Cutometer®, a 6 mm probe was used and the device was set up to generate negative pressure of 450 mbar during 1 s (on-time) following by no pressure during 1s (off time). This cycle was repeated ten times. All the parameters were studied (R, Q and F parameters). For ElastiMeter, a 0.6 mm indentometer was used and the Instant Skin Elasticity (ISE) was calculated.

Skin density

A 50 MHz ultrasound – DermaScan® C (Cortex) was used to evaluate dermis thickness and echogenicity.

Fringe projection system

A fringes projection system AEVA-HE (Eotech) associated with a Visio 4D bench (Eotech) were used to set up the 3D acquisition of knees. As for the photographic bench, we have managed the position of pelvis and feet by adding the same measuring device to position the feet angles, and a new walker system to eliminate any movement during the acquisition. Reproducibility of measurement over time was evaluated and has given good results.
3D images were taken, and a multiple analysis was done to obtain classical roughness parameters but also features density based on local curvature detection (fig. 1). Analysis was adapted to upper or middle part specificities.

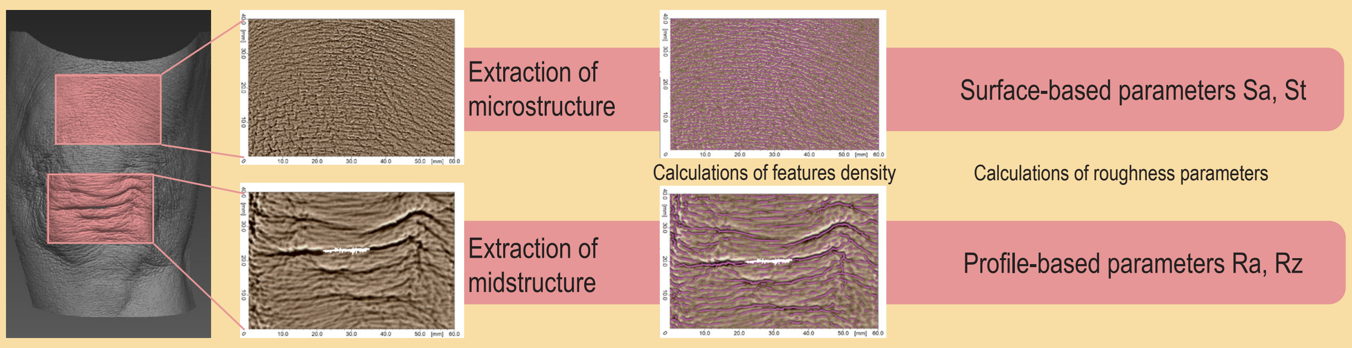


Figure 1: Skin topography analysis pathway

RESULTS

Photographic system

For the method reproducibility, grading by 2 trained experts demonstrated a good (41 %) or very good (45 %) repositioning of volunteers.
The pictures were split in 6 ages categories (20 – 30 – 40 – 50 – 60 – 70 y/o) and the most representative picture for each age category was chosen to build an atlas of knees (Fig. 2).
This result shows that changes appear clearly around 40 y/o and keep going with age.
The changes on upper-part of the knee preferentially involve skin roughness, texture and fine wrinkles. On the middle-part of the knee, changes involve large and deep wrinkles but also sagging.

Figure 2: 2D pictures of knees obtained with photographic bench and representing each age category

Fringe projection system and roughness analysis

An identical atlas with same volunteers was built with 3D acquisitions (fig. 3)

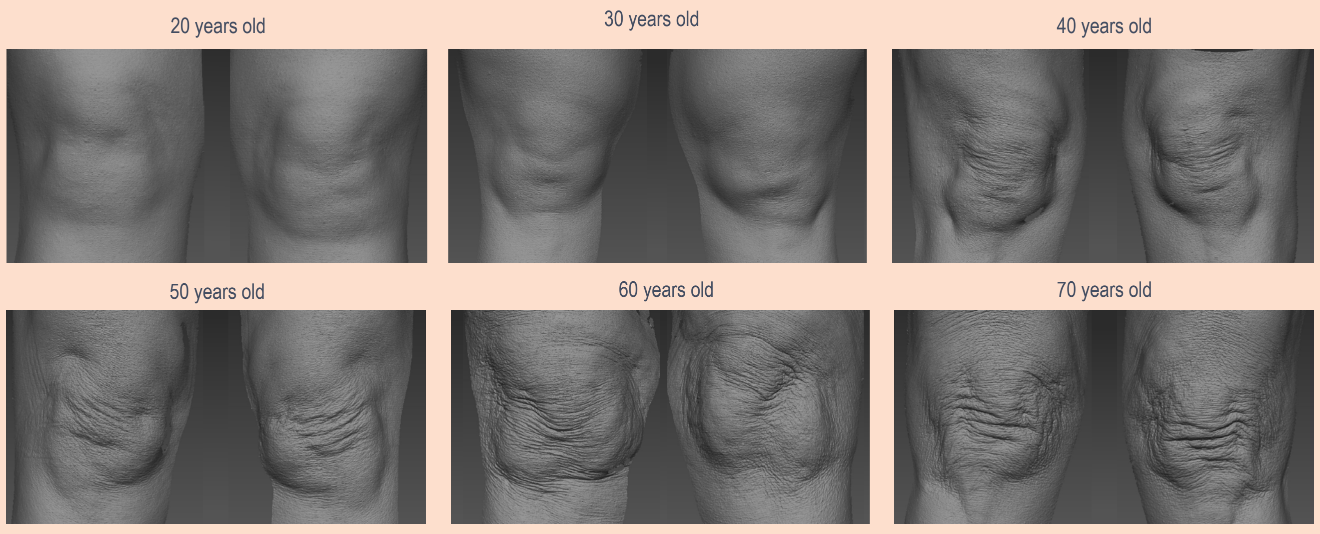
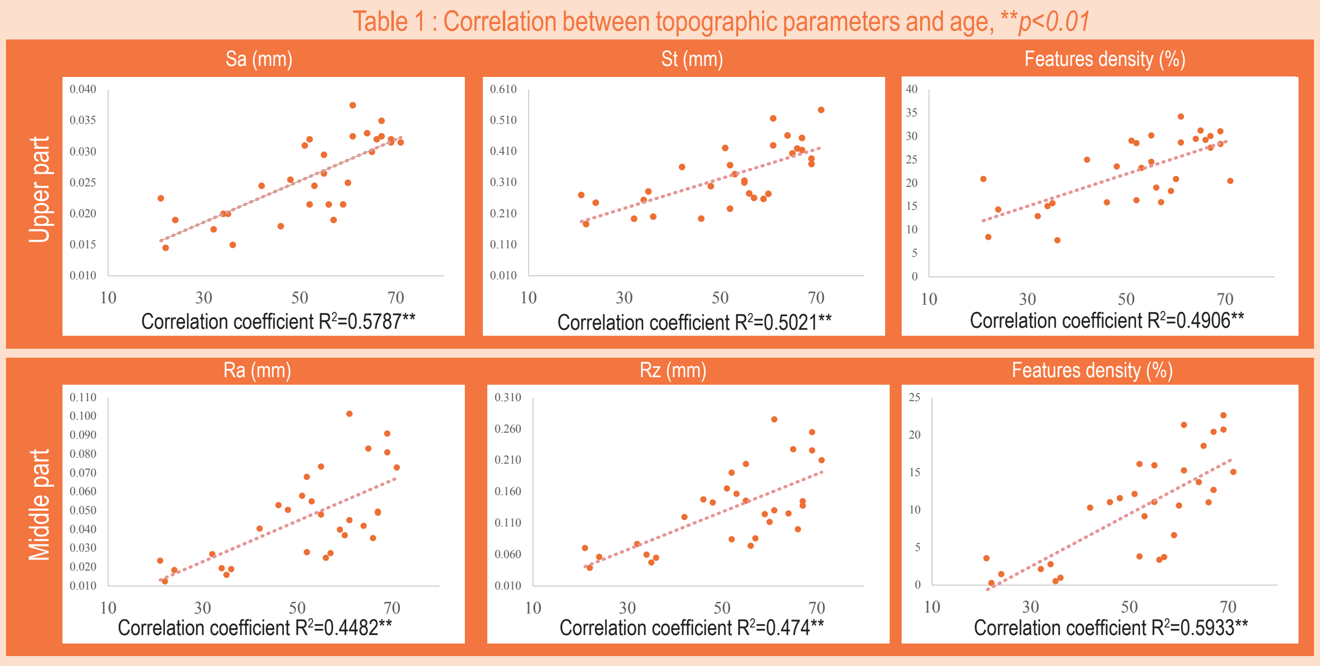


Figure 3: 3D images of knees obtained with fringes projection and representing each age category

For the upper-part of knee, roughness Sa and St, as well as feature density showed a significant correlation with age (table 1).
Identically, for the middle-part of knee, Ra, Rz, and features density showed a significant correlation with age (table 1).

Table 1 : Correlation between topographic parameters and age, $^{**}p<0.01$



The difference between "young", "middle" and "old" was significant for all the parameters (figure 4)

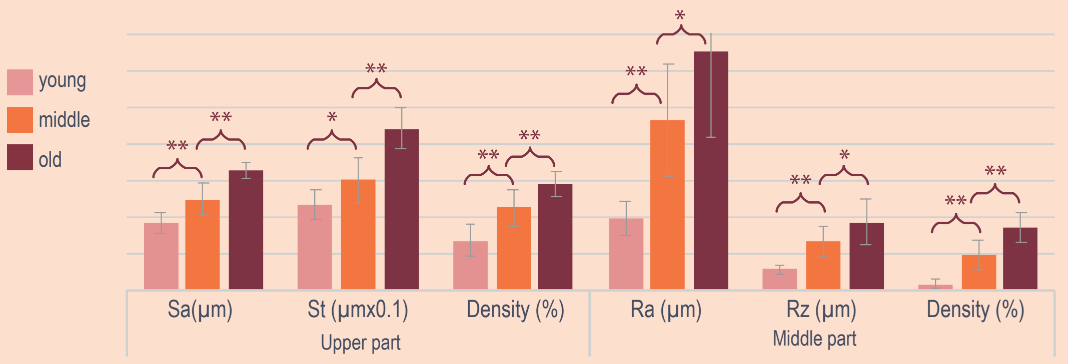


Figure 4: Skin topography parameters obtained with AEVA on upper and middle part of the knees. The figure present parameters and the comparison between young, middle and old age categories. $^*p<0.05$; $^{**}p<0.01$

Skin elasticity - cutometer®

Classical R parameters Ua/Uf (R2), Ur/Ue (R5), Uv/Ue (R6), Ur/Uf (R7) and "skin fatigue" (R4-R1) showed a significant correlation with age (Table 2). The area parameter F3 (skin fatigue) and the Q parameters Q1 (Overal elasticity), Q2 (elastic recovery) and Q3 (viscous recovery) also showed a significant correlation with age (Table 2). The coefficients R2 were all above 0.44 and no difference was seen between upper and middle part of knees.

Table 2: Correlation between cutometer® parameters and age, $^{**}p<0.01$

	R2		R5		R6		R7		R4-R1	
	Upper part	Middle part	Upper part	Middle part	Upper part	Middle part	Upper part	Middle part	Upper part	Middle part
Correlation coefficient (R^2)	**0.5764****	0.5044**	0.5865**	0.6915**	0.4962**	0.4785**	0.6558**	0.75**	0.6187**	0.4423**

	F3		Q1		Q2		Q3	
	Upper part	Middle part	Upper part	Middle part	Upper part	Middle part	Upper part	Middle part
Correlation coefficient (R^2)	0.6394**	0.4665**	0.5959**	0.5884**	0.6438**	0.726**	0.7231**	0.8538**

For next results, only upper part is presented as the results are very similar to those obtained with middle part. The difference between "young", "middle" and "old" was significant for all the parameters except for R6 (Fig. 5).

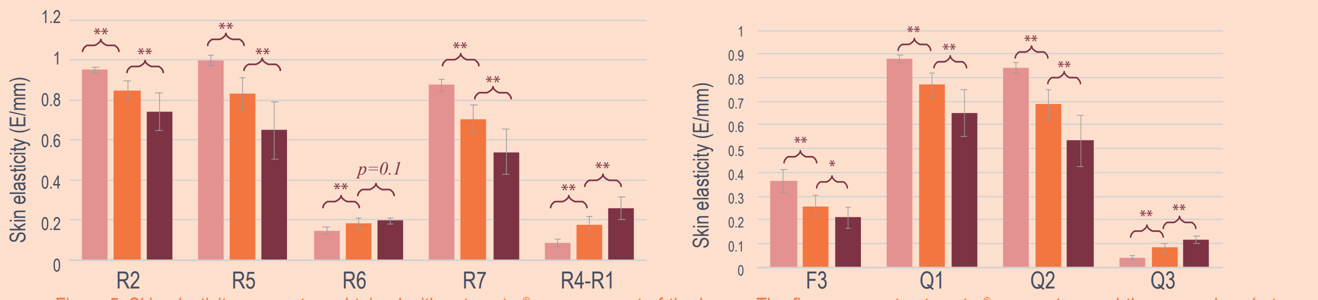


Figure 5: Skin elasticity parameters obtained with cutometer® on upper part of the knees. The figure present cutometer® parameters and the comparison between young, middle and old age categories. $^*p<0.05$; $^{**}p<0.01$

Skin elasticity – ElastiMeter®

The use of ElastiMeter® on middle part of the knee did not provide reproductible values and in consequence, only upper part results are presented here. The Instant Skin Elasticity showed negative correlation with age but this correlation remains low with a correlation coefficient R2 = 0.2449 ($p<0.05$). The difference between "young" and "middle" or "young" and "old" categories are almost significant, both with $p<0.07$ (Fig. 6). However, the comparison between "young" and "middle+old" panelists showed a significant difference with $p<0.05$.

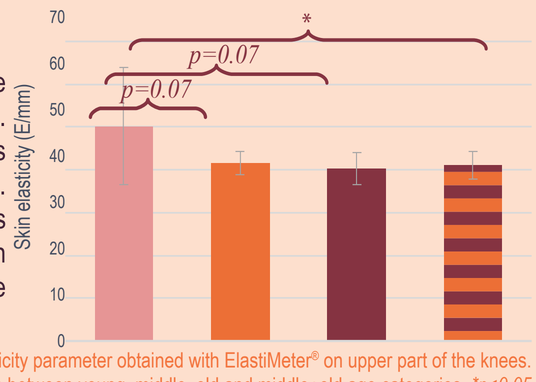


Figure 6: Skin elasticity parameter obtained with ElastiMeter® on upper part of the knees. The figure presents comparison between young, middle, old and middle+old age categories. $^*p<0.05$

Skin density

It was not possible to use the ultrasound probe in the middle part of the knee because of unflatten structures created by patella. The 50 Mhz probe was used for upper part on all the volunteers. Visual observation of each echography and comparison amongst different volunteers failed to show any pattern or relationship with age, either in the density or the thickness of dermis. Thus, no quantification was done on pictures. Moreover, the Sub Epidermal Non-Echogenic Band (SENEB), that classically appears with age was not found here.

CONCLUSION

- Photographic and fringe projection benches have been set up.
- A 2D and 3D atlas of knees with six age categories was done.
- Topography analysis with AEVA demonstrated a correlation with age.
- Elasticity analysis with the Cutometer® has also provided a high correlation with age.
- Analysis can be performed on smooth upper part or heavy wrinkled middle part.
- **A strong multisystem is now available for recruitment and for testing product efficacy.**

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