Wound Healing Revealed by a Novel Automated Indentation Technique

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INTRODUCTION

Mechanical characterization of wound healing in skin samples mostly relies on uniaxial tensile rupture tests, which provide local information along the wound and are disruptive for samples[1]. In this study, we wanted to test the ability of a novel automated indentation technique to non-destructively characterize mechanical properties of the entire wound and its integration with the surrounding skin.

EXPERIMENTAL METHODS

Wounded pig skin samples (4x8cm centered 3 cm incision length) were placed skin surface up on a flat platform of a multiaxial mechanical tester (Fig. 1A) equipped with a 6.35mm diameter spherical indenter under its load cell (Mach-1v500css, Biomomentum Inc., Canada). Following top-view photodocumentation, a position grid (>130 positions) was superimposed over the image. At each position, the tester was programmed to precisely measure overall skin thickness through detection of contact with the surface and to perform an indentation ramp of 1.5 mm at 200 µm/s. Subsequently, the sample was reshaped in two adjacent dumbbell-shaped strips (perpendicularly to the wound), mounted in tension grips (Fig. 1B) and tensile rupture tests were performed at 2 mm/s.

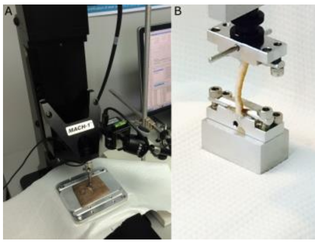

Figure 1. A) Experimental set up of a skin sample on the multiaxial mechanical tester for indentation; B) Experimental set up of an excised strip on a uniaxial mechanical tester for tensile test.

RESULTS AND DISCUSSION

High-resolution mapping of maximum load and thickness were generated (about 30s per position) (Fig. 2). These mappings revealed significant spatial variation of the mechanical properties and thickness over the wound region compared to the uniform properties of the intact skin observed at least 1cm away from the incision site. Also, quantitative information about the hypertrophy/atrophy of the wound could be calculated where scar A revealed a 12.25 mm^2/mm of wound hypertrophy while scar B does not reveal significant hypertrophy. Considering the load at rupture in the tension tests, a correlation could be observed with the maximum load (or thickness) in indentation measured at the rupture site (Table 1).

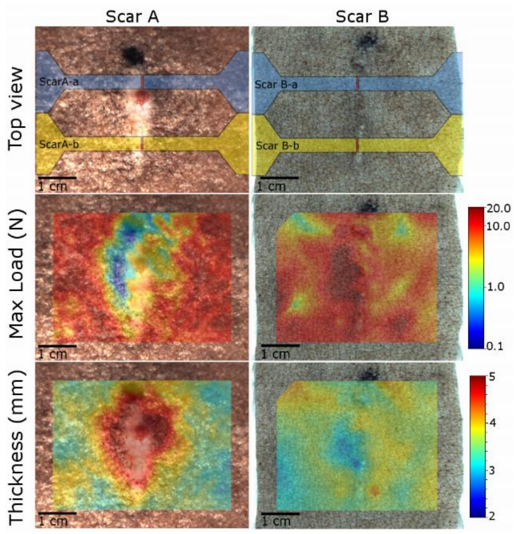

Figure 2. Photodocumentation of the excised strips (tensile test) on each sample and mappings of the maximum load and thickness obtained through the novel indentation technique.

Table 1. Tensile and indentation parameters of strips

	Tensile	Indentation	
	Load at rupture (g)	*Maximum Load (N)*	*Thickness (mm)*
Scar A-a	2053	1.71	5.08
Scar A-b	2266	3.21	4.80
Scar B-a	2922	7.13	3.87
Scar B-b	3729	12.79	3.49

CONCLUSION

Despite the low number of samples (n=2), these results indicate that the novel automated indentation technique can provide a novel assessment of the mechanical properties revealing the 2-dimensional distribution over the wound and its surrounding areas. These measurements can complement the rupture force, which provides insight on the basic mechanical function of the wound along its surface (maintaining the wound closed). Since the technique is non-destructive for the sample, it allows additional analyses (tensile, histology or biochemical assessment) to be performed at matched positions. Moreover, analysis of the relaxation curve could provide viscoelastic parameters. This high spatial resolution and non-destructive technique provides new opportunities when studying wound healing where the number of animals involved could be significantly reduced.

REFERENCES

1. Chao C.Y.L. *et al*., Wound Repair Regen. 19(3):324-329, 2011