Biomechanical properties of each layer of porcine perineal tissues

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Introduction : Data concerning the mechanical properties of the perineum and fetal stresses during delivery are very limited. They are essentially numerical models of the distension of the levator ani muscles. During childbirth, the morphological and dynamic adaptation of the perineum to the fetal presentation depends on its resistance to the stresses induced by the presentation. Under the effect of the compression of the presentation, the perineum becomes thinner until sometimes it tears. In-vivo experimentations raise ethical issues.

Objective: To describe the biomechanical properties of each perineal tissue of the sow in order to better understand perineal tears.

Materiel & Methods: Perineal tissues from fresh dead sow were dissected. One sample was obtained from the skin, the vagina, the external anal sphincter (EAS), the internal anal sphincter (IAS) and anal mucosa. They were tested in quasi-static uniaxial tension using the testing machine Mach-1 (Biomomentum Inc, Canada). The tests were performed in the general fiber direction until failure at 0.1 $mm.s^{-1}$ and at a constant temperature of 21°C. Stress-stretch curves of each perineal tissue before the first damage for each sow was obtained. Hyperelastic coefficients (C1, C2, and C3) were obtained by modeling the curves with nonlinear model (Yeoh model and Martins model). Pearson correlation coefficient was calculated to measure the association between C1 hyperelastic coefficient and the duration between the first microfailure and the complete rupture of each tissue and between C1 hyperelastic coefficient and the number of micro-failures before complete rupture of each tissue.

Results: Ten samples of each layer were analyzed. Mean hyperelastic coefficients C1 and their standard deviation were 37 ± 16 kPa, 200 ± 97 kPa, 28 ± 18 kPa, 18 ± 14 kPa and 138 ± 29 kPa for the perineal skin, the vagina, the EAS, the IAS and the anal mucosa respectively. According to this same sample order, the first microfailure appeared at least at 31%, 26%, 49%, 53% and 21% of stress. No correlation was found between C1 hyperelastic coefficient and the duration between the first microfailure and the complete rupture of each tissue ($p>0.05$) or the number of micro-failures before complete rupture of each tissue ($p> 0.05$).

Conclusion: In this population of fresh dead sow, the vagina was the stiffer tissue. The anal mucosa was the less deformable tissue. The IAS and EAS were the more deformable and the less stiff. But this analysis did not consider the biomechanical properties of contracted muscles. It would be interesting to study the viscoelasticity.

Figure 1. Stress-stretch curves of each perineal tissue before first damage for each sow

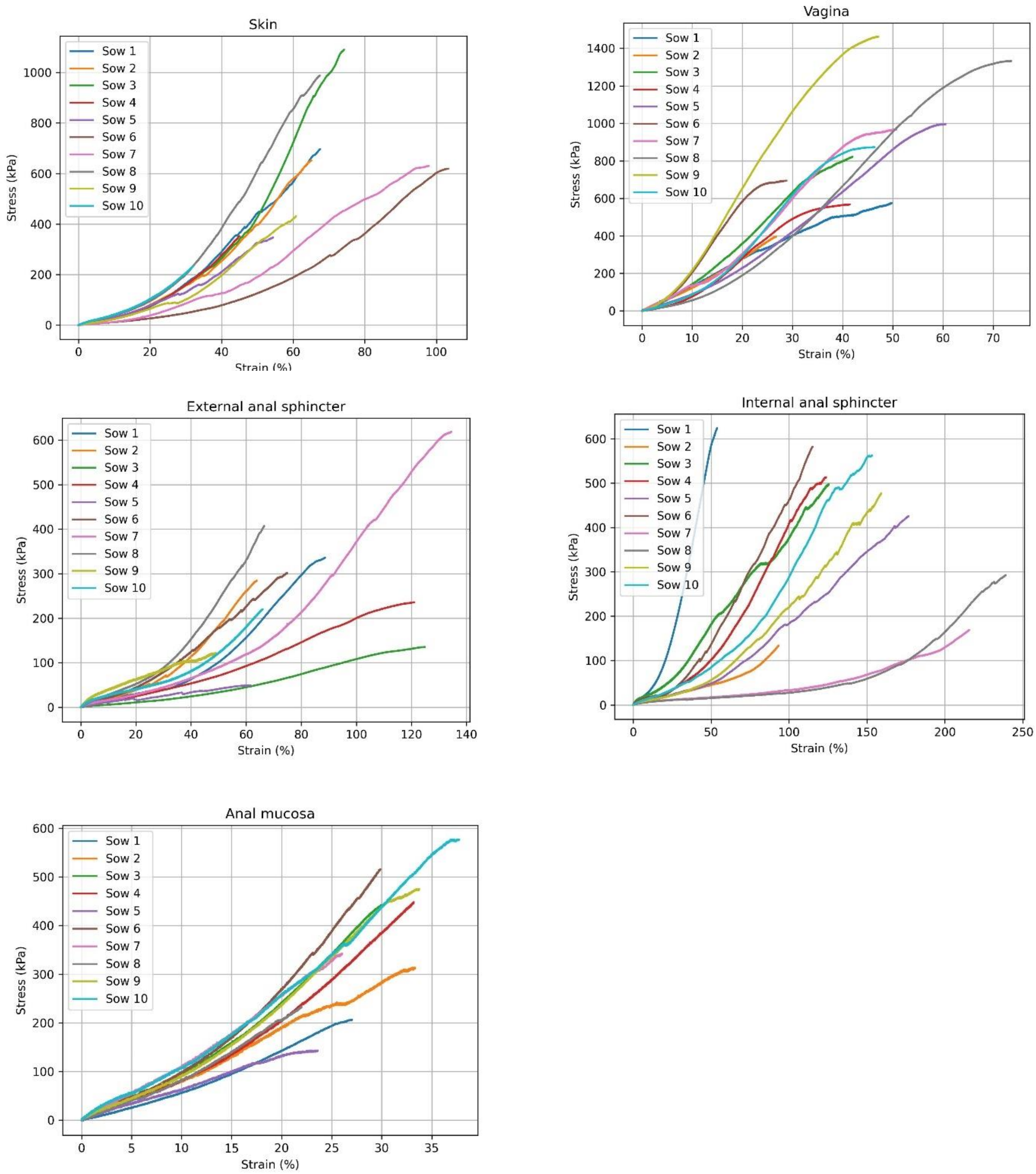

Figure 2. Mean stress-stretch curves and their standard deviation for each perineal tissue before the first damage in this population

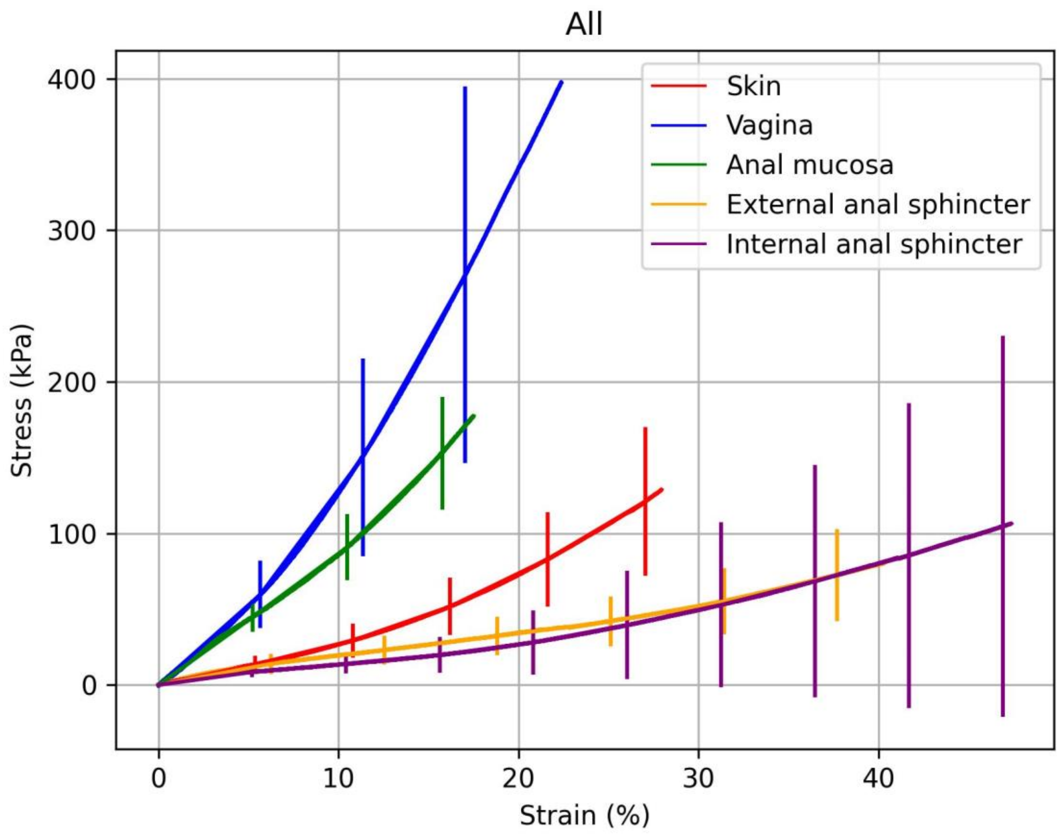

Table 1. Hyperelastic coefficients according to the perineal tissue

Tissue	C1 (kPa)	C2 (kPa)	C3 (kPa)
Skin	37 ± 16	142 ± 65	-16 ± 35
Vagina	200 ± 97	825 ± 661	-1139 ± 1819
EAS	28 ± 18	22 ± 29	2 ± 10
IAS	18 ± 14	49 ± 103	-16 ± 46
Anal mucosa	138 ± 29	422 ± 150	-493 ± 228

Results are expressed as mean ± standard deviation

Table 2. Correlation between C1 hyperelastic coefficient and the duration between the first microfailure and the complete rupture of each tissue

Tissue	Delta T	C1	Pearson's correlation	p
Skin	79 ± 105	37 ± 16	0.5	0.1
Vagina	69 ± 86	200 ± 97	0.6	0.07
EAS	146 ± 168	28 ± 18	0.3	0.4
IAS	151 ± 162	18 ± 14	0.3	0.4
Anal mucosa	166 ± 108	138 ± 29	0.3	0.4

Table 3. Correlation between C1 hyperelastic coefficient and the number of micro-failures before complete rupture of each tissue

Tissue	Number of micro-failures	C1	Pearson's correlation	p
Skin	16 ± 14	37 ± 16	0.4	0.3
Vagina	6 ± 5	200 ± 97	0.4	0.2
EAS	23 ± 19	28 ± 18	0.5	0.1
IAS	18 ± 17	18 ± 14	-0.2	0.6
Anal mucosa	38 ± 23	138 ± 29	0.3	0.4

Table 4. Correlation between delta E (difference of deformation between the first microfailure and rupture point) and the number of microfailure between the first one and the rupture point of each tissue

Tissue	Delta E	Number of microfailures	Pearson correlation	p
Skin	4.3 ± 6.9	2.3 ± 3.9	0.53	0.1
Vagina	1.1 ± 3.3	1.0 ± 3.2	1	**< 0.01**
EAS	3.8 ± 6.6	3.3 ± 7.5	0.65	**0.04**
IAS	8.4 ± 8.7	3.2 ± 3.8	0.87	**< 0.01**
Anal mucosa	1.0 ± 1.5	2.3 ± 3.7	0.91	**< 0.01**

Table 5. Correlation between C3 hyperelastic coefficient and the number of microfailure between the first one and the rupture point of each tissue

Tissue	C3	Number of microfailure	Pearson correlation	p
Skin	-15.7 ± 35.3	2.3 ± 3.9	-0.20	0.6
Vagina	-1138.7 ± 1819.3	1.0 ± 3.2	0.15	0.7
EAS	2.0 ± 10.2	3.3 ± 7.5	0.54	0.1
IAS	-15.7 ± 45.7	3.2 ± 3.8	0.30	0.4
Anal mucosa	-493.2 ± 228.5	2.3 ± 3.7	-0.22	0.5