

**Mechanical response of animal abdominal walls in vitro:
Evaluation of the influence of a hernia defect and a
repair with a mesh implanted intraperitoneally**

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1 Mechanical response of animal abdominal walls *in vitro*:
2 Evaluation of the influence of a hernia defect and a repair with
3 a mesh implanted intraperitoneally

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24 ABSTRACT
25

26 Better mechanical knowledge of the abdominal wall is requested to further develop and
27 validate numerical models. The aim of this study was to characterize the passive behaviour of
28 the abdominal wall under three configurations: intact, after creating a defect simulating an
29 incisional hernia, and after a repair with a mesh implanted intraperitoneally. For each
30 configuration, controlled boundary conditions were applied (air pressure and then contact
31 loading) to the abdominal wall. 3D Local strain fields were determined by digital image
32 correlation. Local strains measured on the internal and external surfaces of the intact
33 abdominal wall showed different patterns. The air pressure and the force applied to the
34 abdominal wall during contact loading were measured and used to determine stiffness. The
35 presence of a defect resulted in a significant decrease of the global stiffness compared to the
36 intact abdominal wall (about 25%). In addition, the presence of the mesh enabled to restore
37 the stiffness to values that were not significantly different from those of the intact wall. These
38 results suggest that intraperitoneal mesh seems to restore the global biomechanics of the
39 abdomen.

40

41 *Keywords:* Biomechanics, mesh repair, digital image correlation, pressure, contact loading.

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43

44 **1. Introduction**

45 Treatment of incisional hernias is a common surgical procedure (Cobb et al., 2003). The
46 laparoscopic repair with mesh implantation improves the treatment of incisional hernia by
47 reducing the rate of recurrence and risk of wound complication (Cobb et al., 2005a). The use
48 of composite mesh, that limits adhesions with abdominal organs, makes the laparoscopic
49 repair easier by putting the mesh in the intraperitoneal location (Cobb et al., 2003). However,
50 problems of recurrence can still happen. Problems of restriction of the abdominal wall
51 mobility or pains may also occur to patients (McLanahan et al., 1997; Müller et al., 1998).
52 Studies on the interaction of mesh with the abdominal wall have been performed. Factors
53 identified as possible causes of recurrence include the size of the implanted mesh compared to
54 the size of the defect (the overlap), and the method of mesh fixation (Binnebösel et al., 2007;
55 Schwab et al., 2008). It has also been suggested that the mesh structure should be improved in
56 order to have similar biomechanical behaviour to the abdominal wall to reduce discomforts
57 (Konerding et al., 2011a; Hernández et al., 2011).

58 Numerical models could be useful to assess the influence of a mesh on the behaviour of the
59 abdominal wall. In particular, such models could be used to evaluate the possible effects of
60 mesh design changes or implantation procedures very early in the design process. However,
61 experimental data on the mechanical response of the abdominal wall are a prerequisite to
62 develop models. Hernández et al. (2011) conducted uniaxial tensile tests on the flat abdominal
63 muscles of rabbits in order to characterize the passive behaviour of the abdominal wall and
64 develop a numerical model of a healthy and a partially herniated repaired abdominal wall of
65 rabbit (Hernández-Gascón et al., 2011). Förstemann et al. (2011) performed uniaxial tensile
66 tests on the linea alba to develop an analytical model of the abdominal wall. While these
67 studies can provide useful data to help in building a model, they cannot be used to evaluate or
68 validate the performance of a whole abdominal wall model subjected to mechanical load.

69 Thus, Konerding et al. (2011a) performed a human cadaver study to validate the model
70 proposed by Förstemann et al. (2011).

71 Song et al. (2006) and Szymczak et al. (2012) studied the complete human abdominal wall
72 response respectively to pressure during a laparoscopic surgery and during different physical
73 exercises. While such studies provide a useful starting point for the validation of model, it
74 only included data on the response of the external surface of the intact human abdominal wall
75 . This is an important limitation for the validation of a model, whose purpose is to study the
76 interaction of the mesh with the wall when implanted on the internal surface. No study
77 comparing the behaviour of the external wall (skin side) and the internal wall (peritoneal side)
78 could be found in the literature.

79 Furthermore, many studies provide experimental results on the mechanical properties of the
80 complete abdominal wall (Song et al., 2006; Konerding et al., 2011a; Junge et al., 2001) and
81 its components (Hernández et al., 2011; Förstemann et al., 2011; Rath et al., 1996, Hollinsky
82 et al., 2007), or on the characterization of meshes only (Junge et al., 2001; Hernández-Gascón
83 et al., 2011). However, only a few studies were found regarding the mechanical response of
84 the abdominal wall with an implanted mesh, and how it may differ from the response of a
85 healthy wall. Müller et al. (1998) studied the difference of abdominal wall mobility between a
86 healthy control group and a group of patients with incisional hernia, who was treated by mesh
87 implantation. Hernández-Gascón et al. (2011) observed the mechanical response of intact
88 abdominal wall and abdominal wall that was repaired using different meshes on rabbits. This
89 study was performed on small animals and only the lateral part of the abdominal wall was
90 considered. Also, samples were characterized by uniaxial test that do not reproduce the
91 physiological loading conditions of the abdominal wall. To the authors' knowledge, no
92 studies compared the behaviour of a same intact abdominal wall, and then implanted with a
93 mesh.

94 Therefore, the current study focused on the anterolateral abdominal wall, where incisional
95 hernias may occur. The objective of this work was to study the response of a same abdominal
96 wall under three different states: intact, with a hernia defect, and repaired. Particular attention
97 was paid to study simultaneously the internal and external surfaces. Boundary and loading
98 conditions were defined to ensure reproducibility and control.

99

100 **2. Materials and methods**

101 *2.1 Specimen & preparation*

102 Anterolateral abdominal walls of six female pigs, aged 4 to 5 months and weighing about 45
103 kg, were used for the current study. The abdominal walls were removed from the animals less
104 than 30 minutes after euthanasia at the VetAgro Sup, Veterinary Campus of Lyon (Marcy
105 l'Etoile, France), and then kept frozen at -20°C until testing. The abdominal walls were cut
106 along the xiphoid process and the costal margins and along the pubic bones and the iliac
107 crests. The lateral incisions were done between the iliac spines and the lower part of the rib
108 cage. Thus the abdominal wall had a triangular shape (Fig. 1). All the layers were preserved:
109 muscles, aponeuroses, adipose tissue, skin and peritoneum. The abdominal walls were thawed
110 at room temperature 16 hours before the test. Just before testing, the external surface of the
111 abdominal wall was shaved. The thickness of each abdominal wall was also measured (Fig. 1)
112 and their average thickness is reported in Table 1. The specimens were sprayed with saline
113 solution to enable their hydration.

114

115 *2.2 Experimental setup*

116 First, the abdominal wall was placed on a hemispherical support (diameter of 9 cm) in order
117 to induce a curvature. Then, it was put on an aluminum plate with a triangular hole exposing
118 the anterolateral abdominal wall. A rubber sheet with the same hole was added to cover the

119 section of the abdominal wall outside the hole. This sheet was clamped using custom designed
120 clamps positioned all around the hole (Fig.2a). As the abdominal wall thickness was not
121 constant over its circumference, the clamps were adjusted to provide adequate tightening in
122 over the whole circumference and prevent local sliding during loading. The abdominal wall
123 was not removed from this fixture until the very end of the experiment.

124 Then, the abdominal wall was positioned on a custom designed aluminium table mounted on a
125 testing machine (INSTRON 8802, High Wycombe, England) (Fig. 2b). The external face of
126 the wall was directed downwards, leading to a natural curvature due to gravity.

127 Physiologically, the abdominal wall can be loaded by contact of the hollow organs or by
128 pressure in case of laparoscopic surgery. So, during the experiment, the abdominal wall was
129 submitted to two mechanical loading cases: contact and air pressure.

130 First, the air pressure was applied on the internal surface (Fig. 3a). A Plexiglas plate was
131 mounted on the top of the aluminium plate in order to create a closed cavity. The Plexiglas
132 plate was transparent, allowing to observe the internal abdominal wall. Compressed air and a
133 manual valve were used to control the pressure in the cavity. At a laparoscopic pressure of 12
134 mmHg, a smaller displacement of the abdominal wall than the one measured by Song et al.
135 (2006) was observed due to strong boundary conditions. So, the pressure was increased until
136 it reaches 50 mmHg, which is in the physiological range of intra-abdominal pressure (Cobb et
137 al., 2005b). Then, it was let to return to atmospheric pressure by opening the valve. The
138 pressure loading cycle was repeated six times. The first 5 cycles enabled to precondition the
139 wall in order to reach a steady state, limiting variability to assess various conditions. Only the
140 sixth cycle of pressurization was used for the data analysis.

141 Then, a contact loading was applied to the internal side using a rigid sphere, to better control
142 the loading conditions for further numerical model (Fig. 3b). After the pressurization test, the
143 Plexiglas plate was removed and the abdominal wall was loaded directly by the rigid

144 Plexiglas sphere (12 cm in diameter) fixed to the actuator of the testing machine. First, the
145 sphere was moved to get in contact with the abdominal wall. Then, the specimen was
146 preconditioned with 5 cycles of 20 mm amplitude at a frequency of 0.5 Hz, close to the
147 respiratory frequency. A displacement of 35 mm, which is in the range of physiological
148 displacement of the abdominal wall (Klinge et al., 1998), was finally applied at a velocity of
149 80 mm per minute. The velocity was slow enough to characterize the quasi-static response
150 and also led to a short duration of test that limit the quite long duration of all the protocol.

151 An incision was made in the middle of the linea alba over a length of 5 cm, which is the size
152 of a medium incisional hernia. The skin was kept intact. The incision was filled with Vaseline
153 and covered with a latex film to avoid air leaks below the skin during pressure loading. The
154 incised abdominal wall was re-loaded. Then a surgical repair was performed using a 10*15
155 cm² Parietex[®] Composite mesh, centred on the defect and fixed on the wall with 20 tackers
156 (AbsorbaTack[®]). The tackers were located at one centimetre of the border of the implant and
157 spaced apart 2 cm. A plastic film (15*20 cm², thickness 10µm) was put on the mesh to avoid
158 air infiltrations between the implant and the peritoneum. Finally the repaired abdominal wall
159 was loaded in the same conditions.

160

161 In summary, the abdominal walls were loaded consecutively by pressure and contact in the
162 three following states:

- 163 - intact abdominal wall,
- 164 - incised abdominal wall (after creating a defect simulating an incisional hernia),
- 165 - repaired abdominal wall (finally after surgical repair by mesh implantation).

166

167 *2.3 Testing duration influence on an intact abdominal wall behaviour*

168 Beforehand, a healthy abdominal wall was tested to assess the effect of time and of the
169 loading sequence on the abdominal wall response. An abdominal wall was subjected to the
170 protocol twice within 4 hours, by switching the different loading cases (pressure, contact and
171 pressure loading again). Between the two series of tests, the specimen was covered with moist
172 gauzes.

173

174

175 *2.4 Measurements*

176 The pressure and the force applied by the sphere to the abdominal wall were measured by a
177 7 bar ENTRAN EPX-N02 pressure sensor and a 1000 N INSTRON force sensor (accuracy
178 0.5%), respectively.

179 Four synchronized SA3 PHOTRON black and white video cameras (Tokyo, Japan) were used
180 to record videos of the abdominal wall during the deformation. Two cameras equipped with
181 35 mm Zeiss lenses (Oberkochen, Germany) were set on the internal surface, and the two
182 others (equipped with 24-70mm Sigma lenses (Tokyo, Japan) in 24 mm position) were set on
183 the external surface. The resolution of the cameras was 1024 by 1024 pixels, which led to
184 approximately 3 pixels per mm in the area of interest. The acquisition frequency was 10
185 frames per second.

186 Before testing, the two faces of the abdominal wall were covered with white make-up to make
187 the background uniform. Then a random speckle pattern was applied with a black paint spray .
188 The speckle enabled to determine 3D local displacement and 3D strain fields by digital image
189 correlation using the VIC3D[®] stereo-correlation software (Correlated Solution, South
190 Carolina, USA).

191

192 *2.5 Data analysis*

193 For the contact loading case, the force versus displacement curves were plotted for the last
194 (6th) loading cycle, and a stiffness in N/mm was worked on. This stiffness was calculated as
195 the slope of the curve determined by linear regression between 26 and 30 mm of displacement
196 (Fig. 4). This interval of displacement defined a common quasi linear area for all the tested
197 abdominal walls. The relative differences of stiffness were calculated between two states,

198
$$\Delta_{state_1-state_2} = \frac{S_{state_2} - S_{state_1}}{S_{state_1}} \times 100, \text{ where } S \text{ is the stiffness.}$$

199 The displacement and strain fields were obtained by stereo correlation for all configurations
200 and for both loading cases on the external wall surface. The strain fields could only be
201 computed on the intact internal wall surface for pressure loading because the Plexiglas sphere
202 hid the internal wall surface during the test. An average strain value was calculated in the
203 central area of the abdominal wall (~ 70mm*105mm between the nipples) from the Lagrange
204 strain values computed by Vic 3D in first principal direction (E1) (Fig. 5). Average strains
205 along longitudinal (linea alba) and transverse lines of the external abdominal wall surface
206 were also calculated for the pressure loading case.

207

208 *2.6 Statistical analysis*

209 A statistical analysis was performed in order to assess the influence of the state (intact,
210 incised, and repaired) of the abdominal wall on its mechanical response. A Wilcoxon non-
211 parametric test (Wilcoxon, 1945) for paired samples was used. A value of $p < 0.05$ was
212 selected to indicate statistical significance. Parameters studied are the stiffness and the
213 average strain. Statistical analysis was performed using Unistat® software (London,
214 England).

215

216 **3. Results**

217 *3.1 Testing duration influence on an intact abdominal wall behaviour*

218 For both mechanical loading, the mechanical response of the abdominal wall was found to be
219 non-linear, with a toe zone followed by a more linear zone . The unloading curve did not
220 overlap with the loading curve. As an example, the force-displacement curves for contact
221 loading are given Fig. 4. A similar mechanical response was obtained whatever the time of
222 test for the pressure and the contact loading, with respectively difference of stiffness of about
223 5% and 10%.

224

225 *3.2 Relation between internal and external surface strains in the intact abdominal wall*

226 The strain fields of the internal and the external abdominal wall surfaces exhibited different
227 patterns as illustrated on Fig. 5. The location of the maximum strain on the internal surface
228 did not match the location of the maximum strain on the external surface. On the internal
229 surface, a region of greater strain near the long edge was observed. On the external surface,
230 there was less strain near the edges and especially at the three corners of the triangle.

231 Table 1 displays the mean value and the standard deviation of the local strains in the central
232 area for the internal and external surfaces for the pressure loading case at 50 mmHg. The
233 average strain in the central area of the external surface (13.7 (2.1) %) was almost 2.6 higher
234 than the mean strain of the internal surface (5.3 (0.7) %), with variation of 23.3%.

235

236 *3.3 Influence of a defect and of mesh repair on the behaviour of the abdominal wall*

237 The curves of the contact loading case for the three studied states are displayed on Fig. 6.
238 Mean stiffness calculated for each state are presented in Fig. 7. The difference of stiffness
239 between intact walls and incised walls was statistically significant ($p = 0.03$). However, the
240 stiffness obtained for intact and repaired states were similar ($p = 0.43$). Relative differences
241 between the abdominal walls states are summarized Table 2. The stiffness of the incised cases

242 was lower by about 25% than the stiffness of intact cases. There was a smaller relative
243 difference of stiffness between intact and repaired walls; the stiffness of intact cases was 6%
244 greater than the stiffness of repaired cases.

245 The mean strains values computed in the central area for the external surfaces of the
246 abdominal wall for each configuration and loading case are displayed in Table 3. For both
247 pressure and contact loading cases, the defect had a significant effect on the strain of the
248 abdominal wall ($p = 0.03$). The defect increased the average strain of about 74% and 35%
249 respectively for the pressure and contact loading. For both loading cases, significant
250 differences of strains were found between incised and repaired states ($p = 0.03$). For the
251 pressure loading case, significant differences of strains were found between intact and repaired
252 states ($p = 0.03$) whereas no significant differences were found for the contact loading case
253 ($p = 0.81$). More elongation was observed in the longitudinal direction than in the transverse
254 direction for each state (e.g. for the repaired state: 15.9 (3.0) % and 15.3 (2.8) % respectively)
255 The defect doubled the average strains along the two directions. No differences were found
256 between incised and repaired states.

257

258 **4. Discussion**

259 In this study, an experimental protocol was developed to characterize the mechanical response
260 of animal passive abdominal wall in three states (intact, incised and repaired) and for two
261 loading cases (increased air pressure similar to a laparoscopic procedure and contact loading).
262 The test of an intact abdominal wall on a day showed that the evolution of the mechanical
263 response of a wall is low (relative difference of 10% for the stiffness). Thus, the duration of
264 the test on a same abdominal wall has limited influence on its behaviour. So, it is expected
265 that differences observed for each configuration can be attributed to the change of state and
266 not to the duration of the protocol.

267 This study was conducted on porcine abdominal walls. An animal model was used to develop
268 the protocol since the anatomical samples were easier to access than those of human. Pig was
269 chosen, because the dimensions of its abdominal wall are close to those of human. Swine are
270 also often used in biomedical research since they have large anatomical and physiological
271 similarities with humans (Swindle et al., 1998). In addition, the experiments on porcine
272 abdominal walls allowed us to validate the repeatability of our protocol. For six specimens
273 with small inter-individual variability (pigs of same weight, about 45kg, and of same age,
274 between 4-5 months) and with very constrained testing boundary conditions, relatively small
275 variability of the stiffness data was observed, with variations in the order of 12.3% for the
276 intact state, 16.5% for the incised state, and 6 % for the repaired state.

277 This study also shows the influence of a defect and a mesh repair on the behaviour of the
278 abdominal wall. The defect decreased the stiffness of the intact abdominal wall by 25% on
279 average and increased the average strain of the abdominal wall by about 74% and 35%
280 respectively for the pressure and contact loading cases. The presence of the mesh in
281 immediate postoperative configuration on an incised abdominal wall enabled to restore the
282 stiffness to values that were not significantly different from those of an intact wall. Other
283 studies interested in the repaired abdominal wall, but when the mesh is integrated. Konerding
284 et al. (2011b) compared the response of different types of meshes that are integrated to the
285 abdominal wall without referring to intact abdominal wall behaviour. This is not the case for
286 the study of Hernández-Gascón et al. (2012) that assessed the response of the repaired
287 abdominal wall and compared it to the response of intact abdominal wall. However, the
288 response was obtained by uniaxial test.

289 For the first time, this study provides data on the strain fields of the abdominal wall for the
290 internal and external surfaces. Szymczak et al. (2012) highlight the interest of studying the
291 internal abdominal wall surface since it is where incisional hernias occur. However, as they

292 performed *in vivo* experiments, they only considered the external abdominal surface. The
293 mean strains computed on the external surface of the abdominal wall were found to be 2.6
294 times greater than those computed on the internal surface of the abdominal wall. For *in vivo*
295 study, only the external surface of the abdominal wall can be measured. It is unclear if the
296 mean ratio found between internal and external strains can be applied because of the
297 difference of boundary conditions and of the muscular activity. Also, specimen to specimen
298 variations on this ratio were relatively high (23.3 %). This suggests that relatively large
299 uncertainties would be associated with the estimation of internal strains solely based on
300 external strains.

301

302 .

303

304 Regarding the present study, some limitations can be mentioned. The effect of freezing was
305 not considered however the literature is often contradictory on the effect of freezing of soft
306 tissues (Van Ee et al., 2000; Clavert et al., 2001; Rubod et al., 2007). During harvesting, there
307 was no opportunity to measure the curvature of the abdominal wall and the shortening of
308 tissues. Thus, the initial curvature and tension could not be reproduced *in vitro*. The initial
309 tension and boundary conditions were not representative of physiological conditions.
310 Perspectives of this study are to approach the physiological conditions with *in vivo*
311 experiments. The anisotropy of the strain was assessed in this study but the analysis is limited
312 by the shape of the current device which is not symmetric. However, these findings
313 correspond with the studies analysing the surface deformation of the *in vivo* human abdominal
314 wall (Song et al., 2006 and Szymczak et al., 2012). Boundary conditions were well controlled
315 in order to develop a numerical model. Due to the strong boundary conditions, the results of
316 stereo-correlation showed artefact near the edges for the pressure loading case. So, the strains

317 patterns analysis was restricted to the central part of the abdominal wall limited by the
318 nipples.

319

320 The main results of this study regarding the stiffness variations between states are currently
321 used to test the validity of numerical models of a porcine abdominal wall. In the future, the
322 same methodology will be used to characterize the passive response of human abdominal
323 walls.

324

325

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328

329 **Conflict of interest statement**

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332

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402 Figure legends:

403

404 **Fig. 1.** Part of the abdominal wall removed from pigs for the tests: (a) The incisions were
405 made along the dotted line. (b) The thickness of the abdominal wall was measured in several
406 points (A to H).

407 **Fig. 2.** Experimental device: (a) Tightening of the abdominal wall between an aluminium
408 plate and a rubber sheet with clamps screwed in the plate. (b) Positioning of the abdominal
409 wall on the table of the testing machine and arrangement of the cameras.

410 **Fig. 3.** Loading mechanisms: (a) Pressure loading, (b) Contact loading

411 **Fig. 4.** Calculation of the stiffness (N/mm) for the contact loading case. The stiffness was
412 computed in the linear region of the curve between 26 and 30 mm of displacement.

413 **Fig. 5.** Lagrange first principal strain fields of the internal (a) and external (b) surfaces of an
414 abdominal wall (sternum side at the top of the figure) subjected to a 50mmHg air pressure.
415 Average strains were calculated in the central area inside the dotted lines.

416 **Fig. 6.** Displacement- Force curves for the contact loading for the three states. Error bars:
417 Standard deviation

418 **Fig. 7.** Mean stiffness calculated for the contact loading case for each abdominal wall state:
419 intact, incised and repaired (n=6). Error-bars: standard deviation.

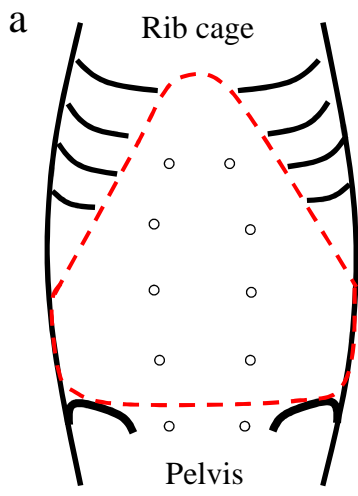
420

421 **Table 1.** Mean Lagrange first principal strains E1 in % calculated for the internal and external
422 surfaces of each abdominal wall for the pressure loading case at 50 mmHg.

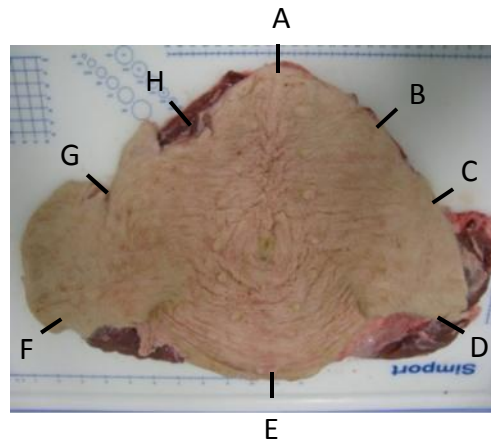
423 **Table 2.** Relative difference of stiffness between the abdominal wall states for the contact
424 loading case.

425 **Table 3.** Mean Lagrange first principal strains E1 in % calculated for the external surface of
426 each abdominal wall for the pressure at 50mmHg and for the contact at 165N.

Fig. 1.



b



Cranial



Caudal

Fig. 2.

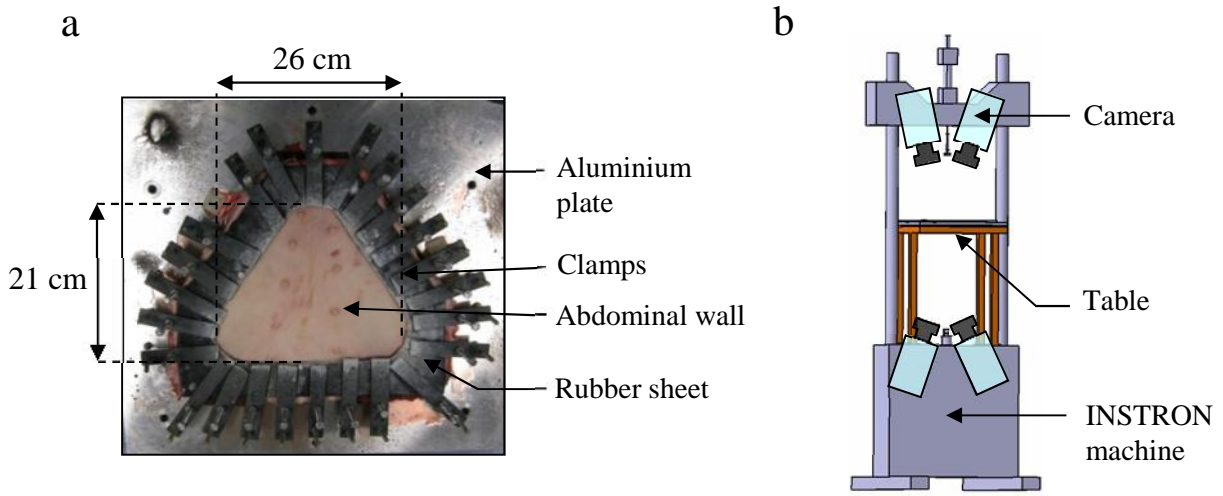
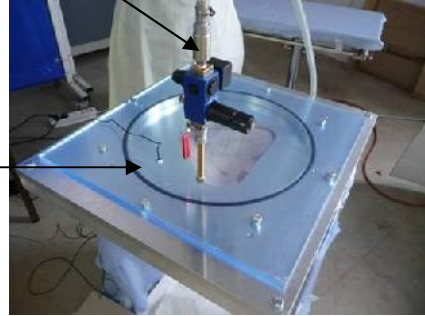
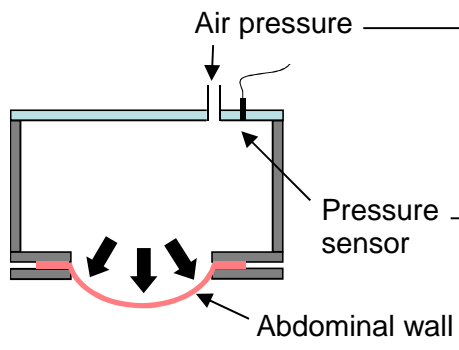


Fig. 3.

a



b

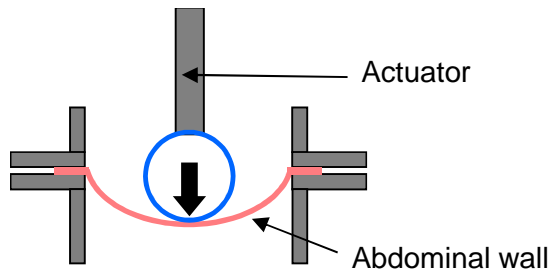


Fig. 4.

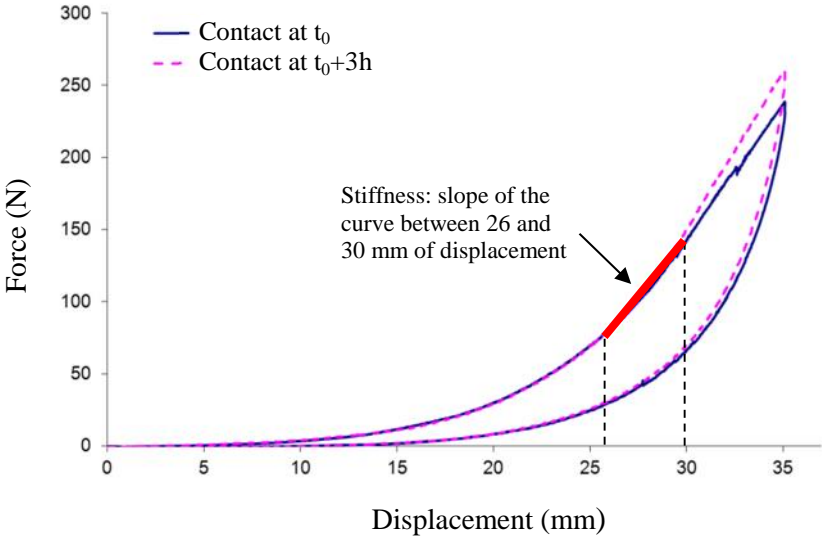
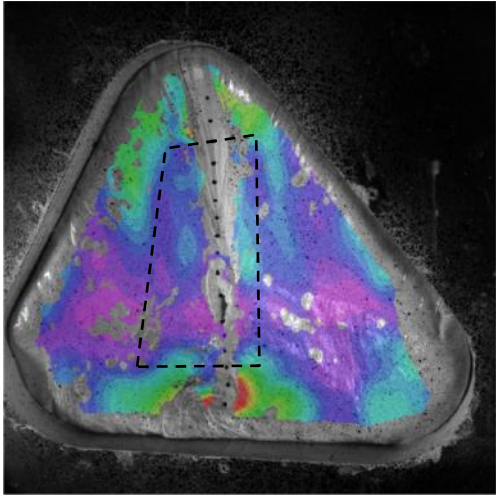
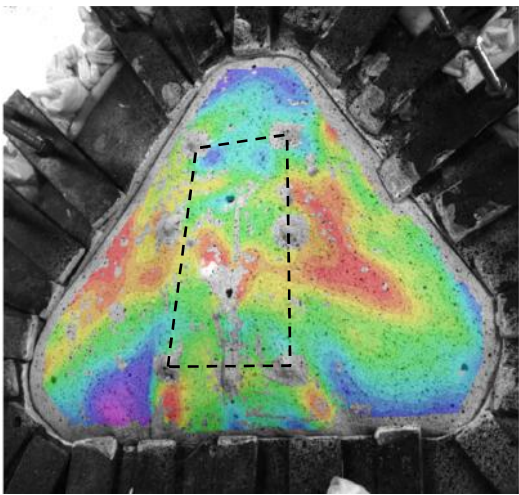


Fig. 5.

a



b



E1

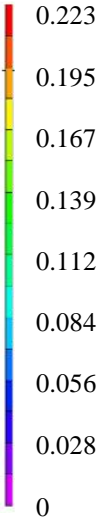


Fig. 6.

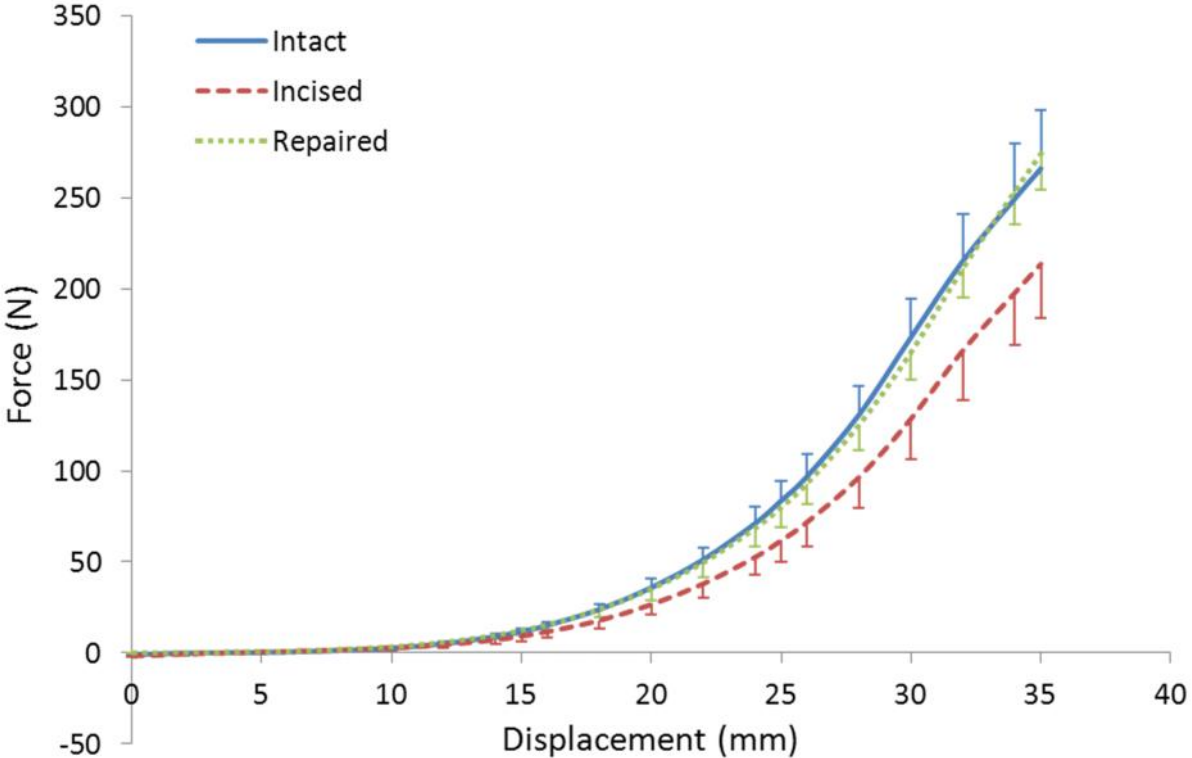


Fig. 7.

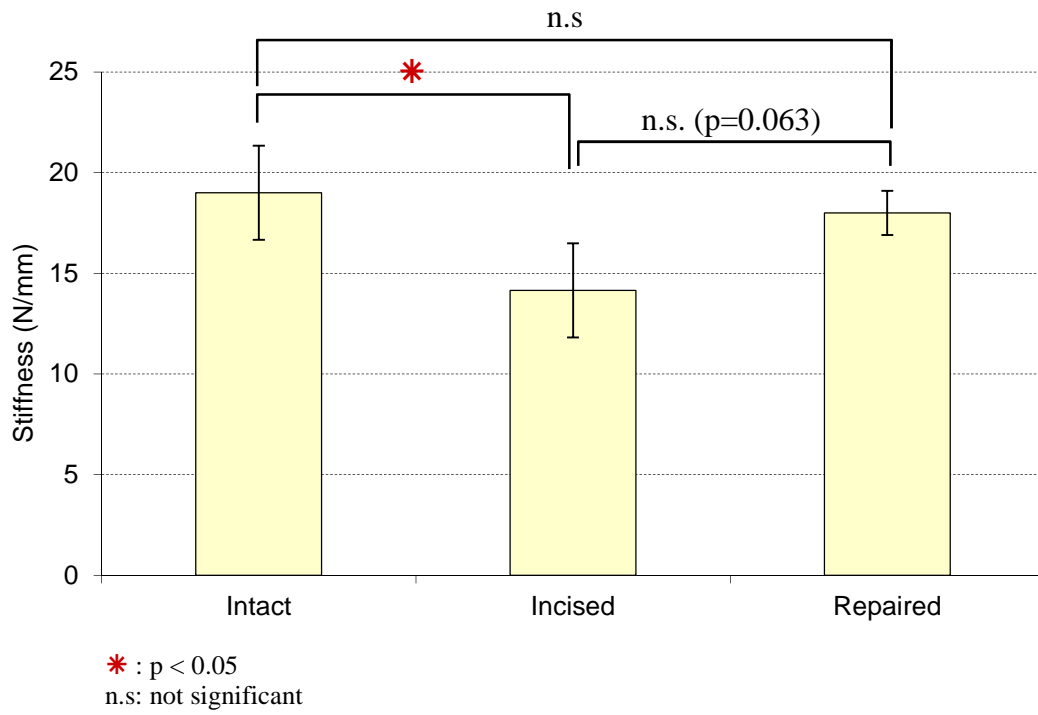


Table 1

	Thickness (mm)	E1 (%) Internal surface	E1 (%) External surface	Ratio E1 Ext. / E1 Int.
Wall 1	28	4.4	13.7	3.1
Wall 2	25	4.5	17.3	3.8
Wall 3	29	5.6	13.4	2.4
Wall 4	27	5.0	10.8	2.1
Wall 5	30	6.6	14.9	2.3
Wall 6	30	5.5	12.0	2.2
<i>Mean</i>	28	5.3	13.7	2.6
<i>SD</i>	1.7	0.7	2.1	0.6

Table 2

	Intact-Incised (%)	Intact-Repaired (%)	Incised-Repaired (%)
Wall 1	-32	-4	42
Wall 2	-26	3	39
Wall 3	-17	-24	-9
Wall 4	-10	23	37
Wall 5	-43	-12	55
Wall 6	-21	-7	18
<i>Mean</i>	-25	-4	30

Table 3

	Mean strain E1 (%) Pressure (P=50 mmHg) – External surface			Mean strain E1 (%) Contact (F=165N) – External surface		
	Intact	Incised	Repaired	Intact	Incised	Repaired
Wall 1	13.7	25.9	20.7	11.0	14.4	13.2
Wall 2	17.3	22.4	20.2	23.0	26.9	19.8
Wall 3	13.4	18.3	17.7	15.5	19.2	15.3
Wall 4	10.8	24.6	15.3	12.5	19.1	14.4
Wall 5	14.9	23.3	22.2	15.2	21.1	15.0
Wall 6	12.0	28.7	21.6	9.8	17.1	12.6
<i>Mean</i>	<i>13.7</i>	<i>23.9</i>	<i>19.6</i>	<i>14.5</i>	<i>19.6</i>	<i>15.0</i>
<i>SD</i>	<i>2.1</i>	<i>3.2</i>	<i>2.4</i>	<i>4.3</i>	<i>3.9</i>	<i>2.3</i>