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## Sectioning of the anterior intermeniscal ligament changes knee loading mechanics

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Abstract: Introduction: The aim of this cadaver research project was to describe the biomechanical consequences of AIML resection on menisci function under load conditions in full extension and 60° flexion.

Methods: Ten unpaired fresh frozen cadaveric knees were dissected leaving the knee joint intact with its capsular and ligamentous attachments. The femur and tibia were sectioned 15 cm from the joint line and mounted onto loading platform. A linear motion x-y table allows the tibial part of the joint to freely translate in anterior-posterior direction. K-scan sensors, were used to define contact area, contact pressure and position of pressure center of application (PCOA) . Two series of analysis were planned: before and after AIML resection, mechanical testing were performed with specimens in full extension and 60° of flexion to approximate heel strike and foot impulsion during the gait. A standard compression load of 1400 N at full extension and 700N at 60° flexion was applied.

Results: Sectioning of the AIML produced mechanical variations bellow the two menisci when specimens were at full extension and loaded to 1400N: increasing of mean contact-pressure ( $\Delta 0.4 \pm 0.2$ MPa, + 15% variation  $p=0.008$ ) and maximum contact-pressure ( $\Delta 1.50 \pm 0.8$ MPa, 15% variation  $p<0.0001$ ), decreasing of tibio-femoral contact area ( $\Delta 71 \pm 51$ mm<sup>2</sup>, - 15% variation  $p<0.0001$ ) and PCOA ( $\Delta 2.1 \pm 0.8$ mm). At 60° flexion, significant differences regarding lateral meniscus mechanical parameters was observed before and after AIML resection : mean contact pressure increasing ( $\Delta 0.06 \pm 0.1$ MPa, +21% variation  $p=0.001$ ), maximal contact-pressure increasing ( $\Delta 0.17 \pm 0.9$ MPa, +28% variation  $p=0.001$ ), mean contact area decreasing ( $\Delta 1.84 \pm 8$ mm<sup>2</sup> 4% variation  $p=0.3$ ), PCOA displacement to the joint-center ( mean displacement  $0.6 \pm 0.5$ mm) .

Conclusion: The section of the intermeniscal ligament leads to substantial changes in knee's biomechanics, increasing femoro-tibial contact pressures, decreasing contact areas and finally moving force center of application which becomes more central inside of the joint.



1 Sectioning of the anterior intermeniscal ligament changes knee loading  
2 mechanics.  
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20 Investigation performed at Aix-Marseille University France.  
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Sectioning of the anterior intermeniscal ligament changes knee loading mechanics.

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~~The Anterior Intermeniscal ligament restrains menisci extrusion during knee loading.~~

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Nicolas Pujol<sup>e</sup> MD.

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**ABSTRACT.**

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80 Introduction: Current knee surgery, including arthroscopic or open procedures places no  
81 emphasis on the identification and preservation of meniscal-belt's anterior part represented by  
82 the anterior intermeniscal ligament (AIML). We do believe that the loss of the meniscal-belt  
83 leads to significantly increased tibio-femoral contact stress due to a greater amount of  
84 « extrusive radial displacement » of the menisci. The aim of this cadaver research project was  
85 to describe the biomechanical consequences of AIML resection on menisci function under  
86 load conditions in full extension and 60° of flexion. We hypothesize that AIML resection will  
87 lead to modified tibio-femoral contact areas and pressures during knee movement.~~The aim of~~  
88 ~~this research project was to describe the consequence of AIML resection on menisci position~~  
89 ~~during knee flexion.~~

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90 Methods: Ten fresh frozen cadaveric knees were dissected leaving the knee joint intact with  
91 its capsular and ligamentous attachments. The femur and tibia were sectioned 15 cm from the  
92 joint line and mounted onto loading platform. A linear motion x-y table allows the tibial part  
93 of the joint to freely translate in anterior-posterior direction. To evaluate tibio-femoral contact  
94 stress, K-scan sensors (Tekscan, South Boston, Massachusetts), were used to define contact  
95 area, contact pressure and position of pressure center of application (PCOA). Two series of analysis  
96 were planed: before and after AIML resection. mechanical testing were performed with  
97 specimens in full extension and 60° of flexion to approximate heel strike and foot impulsion  
98 during the gait. A standard compression load of 1400 N at full extension and 700 N at 60°  
99 flexion was applied.

100 Results: Sectioning of the AIML produced mechanical variations bellow the two menisci  
101 when specimens were at full extension and loaded to 1400N: increasing of mean contact-  
102 pressure (delta 0.4+/-0.2MPa, + 15% variation p=0.008) and maximum contact-pressure  
103 (delta 1.50+/-0.8MPa, 15% variation p<0.0001), decreasing of tibio-femoral contact area

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104 (delta 71+/-51mm<sup>2</sup>, -15% variation p<0.0001) and PCOA (delta 2.1+/-0.8mm). Those elements  
105 were found for the two menisci separately and as well as taken together. At 60° flexion, there  
106 were no substantial differences in term of contact-pressure, maximal contact-pressure, contact  
107 area or PCOA when the menisci were evaluated together, as well as when the medial  
108 meniscus was assessed separately-individually. A significant difference regarding lateral  
109 meniscus mechanical parameters was observed before and after AIML resection : mean  
110 contact pressure increasing (delta 0.06+/-0.1MPa, +21% variation p=0.001), maximal contact-  
111 pressure increasing (delta 0.17+/-0.9MPa, +28% variation p=0.001), mean contact area  
112 decreasing (delta 1.84+/-8mm<sup>2</sup> 4% variation p=0.3), PCOA displacement to the joint-center (  
113 mean displacement 0.6+/-0.5mm).

114 Conclusion: The section of the intermeniscal ligament leads to substantial changes in knee's  
115 biomechanics, increasing femoro-tibial contact pressures, decreasing contact areas and finally  
116 moving force center of application which becomes more central inside of the joint. Those  
117 potentially deleterious modifications in vivo must be confirmed by clinical studies confirming  
118 the interest of preserving or even repairing the anterior intermeniscal ligament.  
119 ~~The section of the intermeniscal ligament leads to substantial changes in knee's~~  
120 ~~biomechanics, increasing tibio-femoral contact pressures, decreasing contact areas and finally~~  
121 ~~moving force center of application which becomes more central.~~

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## INTRODUCTION.

~~The anterior intermeniscal ligament (AIML) of the knee is tightened between the anterior part of the menisci. The AIML is a variable structure<sup>1</sup> described as a small, thick structure, intricated within the retro-patellar fat pad and connected to anterior cruciate ligament fibers<sup>2,3</sup>. Anatomic and MR studies do not coincide<sup>4,5</sup> in contrary to classically admitted “horn insertion” of the AIML, Nelson and Laprade<sup>5</sup> described three types of insertion: type I AIML has attachments to the anterior horn of the medial meniscus and anterior margin of the lateral meniscus, type II AIML has medial attachment to the anterior margin of the medial meniscus and lateral attachment to the joint capsule anterior to lateral meniscus and type III AIML has medial and lateral capsular anterior attachments only with no direct attachments to the anterior horn of the medial meniscus or to the lateral meniscus. (Figure 1)~~

~~In their description Nelson et Laprade<sup>5</sup> found an AIML in 94% of the cases (47/50) when Aydingoz et al.<sup>1</sup> found it in only 53% (121/229) in their MRI evaluation.~~

~~The shock-absorbing function of the menisci arises from their ability to convert an axial load~~

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154 into circumferential hoop stresses, this function is deeply related to a ligament-capsule-  
155 menisci complex as known as the “meniscal belt”<sup>61</sup>. The loss of the meniscal-belt leads to  
156 significantly increased tibio-femoral contact stress due to a greater amount of « extrusive  
157 displacement » of the menisci<sup>7,8,2,3</sup>. At the most anterior part of this belt, the anterior  
158 intermeniscal ligament (AIML) of the knee is tightened between the anterior part of the  
159 menisci. The AIML is a variable structure<sup>4</sup> described as a small, thick structure, intricately  
160 within the retro-patellar fat pad and connected to anterior cruciate ligament fibers<sup>2,3,5,6</sup>.  
161 Anatomic and MR studies do not coincide<sup>1,4,5,4,7,8</sup> : in contrary to classically admitted “horn  
162 insertion” of the AIML, Nelson and Laprade<sup>5,8</sup> described three types of insertion: type I  
163 AIML has attachments to the anterior horn of the medial meniscus and anterior margin of the  
164 lateral meniscus, type II AIML has medial attachment to the anterior margin of the medial  
165 meniscus and lateral attachment to the joint capsule anterior to lateral meniscus and type III  
166 AIML has medial and lateral capsular anterior attachments only with no direct attachments to  
167 the anterior horn of the medial meniscus or to the lateral meniscus. (Figure 1)  
168  
169 In their description Nelson et Laprade<sup>5,8</sup> found an AIML in 94% of the cases (47/50) when  
170 Aydingoz et al.<sup>14</sup> found it in only 53% (121/229) in their MRI evaluation.  
171 Current knee surgery, including arthroscopic or open procedures places no emphasis on the  
172 identification and preservation of this belt at its anterior part, represented by the AIML which  
173 is often injured or neglected. ~~The loss of the meniscal belt leads to significantly increased~~  
174 ~~tibio-femoral contact stress due to a greater amount of « extrusive displacement » of the~~  
175 ~~menisci~~<sup>7,8</sup> =The aim of this cadaver research project was to describe the biomechanical  
176 consequences of AIML resection on menisci function under load conditions in full extension  
177 and 60° of flexion during knee flexion.  
178 We hypothesize that ~~-~~AIML resection will lead to ~~modified-decreased~~ tibio-femoral contact  
179 areas and increased pressures in full extension and 60° of flexion during knee movement.

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182 **METHODS.**

183 Ten unpaired fresh frozen cadaveric knees (6 right/ 4 left knees) were chosen out of the knees  
 184 available at centre de Thanatopraxie de la Faculté de Médecine de Marseille. Specimens were  
 185 procured with funding support from Société Francophone d’Arthroscopie (SFA). Specimens  
 186 selection was done after macroscopic and radiographic inspection to rule-out bone and joint  
 187 anomalies, specimens with substantial knee arthritis, bone deformities or evidence (scar,  
 188 hardware... ) of previous surgery were excluded. Institutional review board approval was not  
 189 required because of the use of de-identified cadaveric specimens. The average age of the  
 190 cadaveric specimens was 48 years (42 to 76 years). Each specimen was maintained in a  
 191 freezer at 0°C before use and then thawed to room temperature for testing. Knees were  
 192 dissected leaving the knee joint intact with its capsular and ligamentous attachments. The  
 193 femur and tibia were sectioned 15 cm from the joint line and potted onto custom jigs made of  
 194 polymethylmetacrylate cement. Specimens were mounted onto an Instron 5566-A® device  
 195 (Instron™, Norwood Massachusetts, USA). A linear motion x–y table allows the tibial part of  
 196 the joint to freely translate in anterior–posterior direction. This setup allowed 1 degrees of  
 197 freedom in flexion–extension, during axial compression, thereby minimizing shear stresses  
 198 during the loading process. (Figure 2)

199 To evaluate tibio-femoral contact stress, K-scan 4400 piezoresistive sensor system (Tekscan,  
 200 South Boston, Massachusetts), with a standard pressure range of 62 MPa, and sensor density  
 201 of 62 per cm<sup>2</sup>, was used <sup>9,109.10</sup>. Anterior and posterior horizontal- 3cm capsulotomies were  
 202 made; (splitting horizontally the anterior and superficial part of the medial collateral ligament  
 203 and doing a sub-meniscal dissection on the lateral side) and sensors were inserted carefully  
 204 avoiding the anterior and posterior horns of the menisci, and the insertional ligaments)

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205 ~~were made to insert pressure sensors~~ below the two menisci following a previously described  
206 method<sup>72</sup>. Calibration was performed following information provided by the  
207 manufacturer<sup>7,11,12,11,12</sup>. A new sensor was used for each knee for two series of mechanical  
208 testing. Sensors were first conditioned by subjecting it to three cycles of axial loading from 0  
209 to 1800 N (130% of the compression load to be applied).

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210 Two series of analysis were planed : specimens in full extension (Figure 3) and 60° of flexion  
211 (Figure 3) to approximate heel strike and foot impulsion during the gait<sup>13,13</sup>. A standard  
212 compression load of 1400 N at a rate of 10 mm/min was applied to the knee in extension and

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213 held for 10 s, ~~then after, positioning the knee a 60° flexion. The 1400 N load was selected to~~  
214 ~~approximate 2 times body weight for an average 70 kg individual<sup>14</sup>.~~ A standard compression  
215 load of 700 N at a rate of 10 mm/min was applied, ~~to the knee at 60° of flexion to avoid~~  
216 ~~specimens' fracture.~~ Each ~~knee specimens~~ was ~~re-~~tested ~~after~~ 15 min intervals, to allow the  
217 knee to return to its unstressed state ~~prior to each loading~~. The AIML was then sectioned with  
218 ~~an #11 surgical-surgical blade, starting 1cm above joint line, cutting-down with direct~~  
219 ~~superior visualization~~ through the fat-pad ~~until tibial bone contact (Figure...),~~ and the two  
220 series of test were repeated. ~~The 1400 N and 700N load were~~ ~~as selected to approximate 1 and~~  
221 ~~2 time(s) body weight for an average 70 kg individual<sup>14,14</sup>.~~ Contact pressure, contact area,

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222 and a contact map were recorded in real-time with two differents analysis using Tekscan I-  
223 scan Pressure Measurement System software (Tekscan, South Boston, Massachusetts): 1/  
224 Menisci evaluated together or 2/ medial/lateral meniscus evaluated separately. Tekscan I-scan  
225 Pressure Measurement System software (Tekscan, South Boston, Massachusetts). Allowing  
226 us to define four parameters of interest: Mean contact pressure (MPa from 0 to Maximum),  
227 Peak contact pressure (MPa), Mean contact area (mm<sup>2</sup> from 0- Maximum) and displacement  
228 of pressure center of application (P-COA: mm difference regarding mean position from 0-  
229 Maximum) on a X-Y axis.

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231 *Statistics*

232 Based on a previous research investigating on tibio-femoral contact pressure after AIML  
233 resection<sup>72</sup>, we designed our study to be able to detect  $\geq$  a 10% ~~variation variation~~ of mean  
234 contact pressure bellow both medial and lateral meniscus ( $\Delta \geq 0.4$  ~~+/-0.4~~ MPa; baseline  
235  $3.7$  ~~+/-0.7~~ MPa for the medial meniscus and  $1.9$  ~~+/-0.6~~ MPa for the lateral meniscus) with a  
236 statistical power of 80%. Both calculations are for a two-sided test with alpha of 0.05 and 1-  
237 Beta of 0.8.

238 Statistical comparison of the variables pre- and post-sectioning was made using a two-tailed  
239 paired t test,  $p < 0.05$  was taken to be statistically significant.

240

241 **RESULTS.**

242 All dissected specimens had a distinct AIML that could be identified during dissection in-  
243 between the two series of mechanical testing. Contact pressure and contact area data for both  
244 compartments were simultaneously measured in real time for every specimen.

245 Sectioning of the AIML produced the following mechanical variations below the two menisci  
246 when specimens were at full extension and loaded to 1400N: increasing of mean contact-  
247 pressure increases ( $\Delta 0.4$  ~~+/-0.2~~MPa, + 15% variation  $p=0.008$ ) and maximum contact-  
248 pressure ( $\Delta 1.50$  ~~+/-0.8~~MPa, 15% variation  $p < 0.0001$ ), decreasing of tibio-femoral contact  
249 area ( $\Delta 71$  ~~+/-51~~mm<sup>2</sup>, -15% variation  $p < 0.0001$ ), displacement of PCOA to the joint-center.  
250 (displacement  $2.1$  ~~+/-0.8~~mm). Those elements were found for the two meniscus separately and  
251 taken together. (table 1)

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252 | When the specimens were evaluated at 60° flexion, we did not find significant differences in  
253 | term of contact-pressure, maximal contact-pressure, contact area or PCOA when the menisci  
254 | were evaluated together, as well as when the ~~internal-medial~~ meniscus was assessed  
255 | ~~separately-individually~~.

256 | We found significant differences regarding lateral meniscus sensor before and after AIML  
257 | resection : mean contact pressure increased (delta 0.06+/-0.1MPa, +21% variation p=0.001),  
258 | maximal contact-pressure increased (delta 0.17+/-0.9MPa, +28% variation p=0.001), mean  
259 | contact area decreased (delta 1.84+/-8mm<sup>2</sup> 4% variation p=0.3), PCOA moved to the joint-  
260 | center (delta 0.6+/-0.5mm) (Table 2).

261

## 262 | **DISCUSSION.**

263 | The main result of our study is that intermeniscal ligament resection leads to substantial  
264 | changes in knee' biomechanics: increasing the femoro-tibial contact pressure, decreasing  
265 | tibio-femoral contact area and modifying force COA's position which becomes more central.

266 | These findings could be explained by a meniscal~~us's~~ extrusion leading to 1/ an earlier contact  
267 | between the femur and the tibia, 2/ a more central pressure Center of Application, 3/ a smaller  
268 | contact area and higher maximal contact pressure. (Figure 5). Our hypothesis that  
269 | intermeniscal ligament resection's lead to ~~knee meniscus's extrusion~~mechanical changes is  
270 | verified by our model.

271 | These elements were found below the lateral meniscus both in full extension and at 60 °of  
272 | flexion, an below the medial meniscus in full extension.

273 | In a recent Finite Elements study, Guess et al.<sup>83</sup> reported that the AIML stretches  
274 | proportionally following axial loading of the knee. AIML resection in their models leads to a  
275 | decreased meniscus ability to absorb and transmit femoro-tibial strains. Those elements are

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276 confirmed by our results as AIML resection modified pressure, contact area and force COA's  
277 position.

278 | Poh et al.<sup>+72</sup> published in 2009 a study similar to ours, based on Tekscan analysis of 6  
279 specimens loaded to 1800N at full extension, they reported a non-statistically significant  
280 variation after AIML resection regarding global contact pressure (2.73 to 2.84 MPa, p = 0.27)  
281 and global contact-area (777 to 739 mm<sup>2</sup>, p = 0.06). Their separate evaluation of the two  
282 menisci, demonstrated higher variation of mean contract pressure ( $\Delta=27\%$ ), peak contact  
283 pressure ( $\Delta=22\%$ ) and contact area ( $\Delta=13\%$ ) below the lateral meniscus. Those results are  
284 consistent with those reported in our study and even if their study was powered to detect 10%  
285 variations in mean contact pressure after AIML resection, their sample size was probably not  
286 sufficient to obtain adequate statistical power to evaluate the two menisci separately.

287 | Paci et al.<sup>+515</sup> evaluated effect of AIML resection below the medial meniscus of 5 knees  
288 loaded to 1000N in five different position from 0 to 60 ° of flexion. They found a significant  
289 difference in terms of mean contact pressure from 20 to 50 ° with a maximum at 40° (3.68 to  
290 4.69 MPa, ( $\Delta=27.5\%$ ) but no significant difference at 0°, 10° and 60 ° flexion. In our study,  
291 we selected a lower load when our specimens were flexed to 60° (700N) to avoid specimens  
292 destruction related to a direct loading on fragile femoral diaphysis.

293 AIML mechanical and anatomical properties have been deeply investigated in the last decade.

294 | Abreu et al.<sup>+616</sup> found a direct link between AIML lesion and meniscal tear, with more than  
295 70% of associated simultaneous lesions when AIML was attached to the anterior part of the

296 | medial meniscus. Yildirim et al.<sup>+717</sup> have demonstrated a presence of nerve and  
297 mechanoreceptor structures within the AIML in their histological study, confirming a  
298 potential role in knee proprioception. This mechanical role can no longer be assured when the  
299 AIML is cut, modifying knee joint mechanics with smaller contact aera and thus higher

300 | strains between femoral and tibial cartilage. Amadi et al.<sup>+414</sup> demonstrated this “meniscal-

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301 belt” loss might lead to arthritis when resecting femoro-meniscal ligaments . Therefore, its  
302 identification and repair should be considered in the same way as described by Haut Donahue

303 <sup>1818</sup>.

### 304 **Limits and strengths.**

305 Our study bears several limitations, foremost our sample size is small but satisfied 80%  
306 statistical power requirement. We used a cadaveric model necessitating a wide subject age  
307 range. We tried to avoid bias attributable to specimens condition by a careful selection based  
308 on X-ray analysis and cadaver conservation. We did not performed MRI evaluation to ensure  
309 the presence of an intermeniscal ligament which remains a variable structure according to

310 MRI studies. De Abreu et al <sup>1616</sup> found it on 73.5% of their MRI analysis when Marcheix et  
311 al <sup>1919</sup> found it in 90% of their knees. During the MRI analysis, it was detected in 83% for  
312 Marcheix et al <sup>1919</sup> and in 62.2% for Aydin et al <sup>47</sup>. Aydingoz et al <sup>14</sup> found AIML in 53% of  
313 the knees during MRI and 67% of the same knees during arthroscopic identification, defining  
314 arthroscopy as the gold standard. In our study, an AIML was observed in every knee during  
315 dissection, which is in line with most anatomical studies <sup>4,5,7,8</sup> .

316 More, the effects of AIML on knee biomechanics can vary according to anatomic variation. In  
317 this study, we did not perform MRI evaluation to assess specimens’ anatomical positioning of  
318 the AIML. Thus, Subgroup analysis on a larger sample size would be advisable to obtain data  
319 regarding relationship between Nelson et Laprade <sup>8</sup> AIML insertion and potential effect on  
320 pressure parameters described in our results.

321 We chose to apply a 700 N and 1400 N in extension following Morrison et al study <sup>1313</sup> ,  
322 according to the authors, during the gait a 2 to 4 times the body weight is applied to the knee,  
323 with a maximum when during heel-strike, close to limb’s full extension. Mundermann's in  
324 vivo study <sup>2020</sup> also measure maximal (peak) pressure when the knee was flexed at 8.5 ° with  
325 a force reaching 2 times the body weight.

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326 We only loaded our specimens to 700N in flexion, the loading apparatus and the quality of  
327 cadavers bones did not allow the application of 1400N. However, previous studies show that  
328 forces inside of the knee are substantially lower during knee flexion<sup>2421</sup>.

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329 The strengths of the study are built on a direct comparison before and after section of the  
330 inter-meniscal ligament, measurements done in extension and flexion, on the two meniscus  
331 separately and together, with the largest sufficient number of specimens of the actual

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332 literature<sup>7,152,15</sup>. Tekscan sensors, we used in this study are recognized to be the most precise  
333 and accurate device for pressure analysis<sup>11,1311,13</sup>.

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334 ~~Based Finally, on our hypothesis that the meniscus do not function as two separate entities but  
335 as a complex load distributing system,~~ we were able to demonstrate that distribution of

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336 pressure was altered when the AIML was resected. Our results confirm a fundamental role of  
337 the AIML; when this ligament is absent, the "meniscal lasso" system is no longer competent  
338 and a phenomenon of meniscal extrusion occurs, generating a central early femoro-tibial  
339 contact, increasing the stress to a deleterious threshold (>5MPa)<sup>2222</sup>.

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343 CONCLUSION.

344 The section of the intermeniscal ligament leads to substantial changes in knee's  
345 biomechanics, increasing femoro-tibial contact pressures, decreasing contact areas and finally  
346 moving force center of application which becomes more central inside of the joint.

347

348 CLINICAL RELEVANCE.

349 AIML resection performed ex-vivo in this study. Those might potentially be deleterious  
350 modifications in vivo. must be confirmed by Clinical studies Focusing confirming the on

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351 interest of preserving or even repairing the anterior intermeniscal ligament are needed to  
352 evaluate those ex-vivo elements.-

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354

#### 355 **Conflict of Interest:**

356 MO JF : Nothing to disclose.

357 NP : Educationnal consultant Zimmer/Biomet, Smith et Nephew

358 PBeaufils : Educationnal consultant Zimmer/Biomet, Smith et Nephew,. Editor in Chief of Orthopaedics and

359 Traumatology, Surgery and Research

360 PBoisrenoult : Educationnal consultant Smith et Nephew

361 Funding : SFA

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**FIGURES LEGEND:**

Figure 1: Scheme illustrating three Laprade and Nelson AIML insertion (A: Type 1, B: Type 2, C: Type 3) types on a left knee tibial plateau Superior view.

Figure 2: Showing Specimen preparation after sensor insertion at full extension (A) and at 60° Flexion (B) in a profile view of a left knee and a frontal view of a right knee (C)

Figure 3: Anatomical Superior view of a left knee during final dissection confirming AIML section.

Figure 4: Scheme illustrating our hypothesis on a left knee: AIML (dashed line) resection leads to meniscus's (dotted triangles) extrusion with an earlier contact between the femur and the tibia (sensors: yellow to red signal) . This early contact was indirectly recorded by our Tekscan evaluation as a more central pressure Center of Application, a smaller contact area and higher maximal contact pressure.

<u>EXTENSION</u> <u>1400N</u>	<u>Pressure</u> <u>medial</u> <u>Meniscus</u> <u>(MPa)</u>	<u>Pressure</u> <u>lateral</u> <u>Meniscus</u> <u>(MPa)</u>	<u>Global</u> <u>Pressure</u> <u>(MPa)</u>	<u>Peak</u> <u>Pressure</u> <u>medial</u> <u>Meniscus</u> <u>(MPa)</u>	<u>Peak</u> <u>Pressure</u> <u>lateral</u> <u>Meniscus</u> <u>(MPa)</u>	<u>Global</u> <u>Peak</u> <u>Pressure</u> <u>(MPa)</u>	<u>Contact</u> <u>area</u> <u>medial</u> <u>Meniscus</u> <u>(mm<sup>2</sup>)</u>	<u>Contact</u> <u>area</u> <u>lateral</u> <u>Meniscus</u> <u>(mm<sup>2</sup>)</u>	<u>Global</u> <u>Contact</u> <u>area</u> <u>(mm<sup>2</sup>)</u>
<u>AIML</u>	<u>3.20+/-0.87</u> <u>(0.84-6.40)</u>	<u>0.61+/-0.45</u> <u>(0-2.91)</u>	<u>2.81+/-</u> <u>0.69</u> <u>(0.11-5.70)</u>	<u>8.14+/-1.83</u> <u>(0.64-11.02)</u>	<u>3.84+/-1.42</u> <u>(0-6.30)</u>	<u>9.53+/-</u> <u>1.77</u> <u>(0.13-</u> <u>11.23)</u>	<u>341.87+/-</u> <u>146.60 (37-</u> <u>521)</u>	<u>211+/-</u> <u>142.86</u> <u>(0-405)</u>	<u>552.87+/-</u> <u>148.40</u> <u>(37-926)</u>

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<b><u>AIML -</u></b>	<u>3.63+/-0.96</u> <u>(0.38-7.10)</u>	<u>0.73+/-0.42</u> <u>(0-2.87)</u>	<u>3.21+/-</u> <u>0.75</u> <u>(0.13-6.41)</u>	<u>9.31+/-1.98</u> <u>(0.71-</u> <u>11.31)</u>	<u>4.61+/-1.23</u> <u>(0-7.24)</u>	<u>11.03+/-</u> <u>2.11</u> <u>(0.22-</u> <u>12.01)</u>	<u>301+/-98.12</u> <u>(21-501.54)</u>	<u>181+/-</u> <u>107.65</u> <u>(0-345)</u>	<u>482+/-</u> <u>112.62</u> <u>(21-</u> <u>846.54)</u>
<b><u>Mean</u></b> <b><u>Difference</u></b> <b><u>(%)</u></b>	<u>0.43</u> <u>(13%)</u>	<u>0.12</u> <u>(20%)</u>	<u>0.40</u> <u>(14%)</u>	<u>1.17</u> <u>(14%)</u>	<u>0.77</u> <u>(20%)</u>	<u>1.50</u> <u>(16%)</u>	<u>-40.87</u> <u>(-12%)</u>	<u>-70.87</u> <u>(-13%)</u>	<u>-30</u> <u>(-14%)</u>
<b><u>p</u></b>	<u>0.04</u>	<u>0.01</u>	<u>0.03</u>	<u>0.02</u>	<u>0.02</u>	<u>0.01</u>	<u>0.04</u>	<u>0.001</u>	<u>0.04</u>

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Table 1. Results of the full extension 1400N loading mechanical testing analysis.

AIML: intact anterior intermeniscal ligament

AIML - : resected anterior intermeniscal ligament

<b><u>FLEXION</u></b> <b><u>700N</u></b>	<b><u>Pressure</u></b> <b><u>medial</u></b> <b><u>Meniscus</u></b> <b><u>(MPa)</u></b>	<b><u>Pressure</u></b> <b><u>lateral</u></b> <b><u>Meniscus</u></b> <b><u>(MPa)</u></b>	<b><u>Global</u></b> <b><u>Pressure</u></b> <b><u>(MPa)</u></b>	<b><u>Peak</u></b> <b><u>Pressure</u></b> <b><u>medial</u></b> <b><u>Meniscus</u></b> <b><u>(MPa)</u></b>	<b><u>Peak</u></b> <b><u>Pressure</u></b> <b><u>lateral</u></b> <b><u>Meniscus</u></b> <b><u>(MPa)</u></b>	<b><u>Global</u></b> <b><u>Peak</u></b> <b><u>Pressure</u></b> <b><u>(MPa)</u></b>	<b><u>Contact</u></b> <b><u>area</u></b> <b><u>medial</u></b> <b><u>Meniscus</u></b> <b><u>(mm<sup>2</sup>)</u></b>	<b><u>Contact</u></b> <b><u>area</u></b> <b><u>lateral</u></b> <b><u>Meniscus</u></b> <b><u>(mm<sup>2</sup>)</u></b>	<b><u>Global</u></b> <b><u>Contact</u></b> <b><u>area</u></b> <b><u>(mm<sup>2</sup>)</u></b>
<b><u>AIML</u></b>	<u>0.47+/-</u> <u>0.24</u> <u>(0.12-</u> <u>0.98)</u>	<u>0.27+/-</u> <u>0.32</u> <u>(0-1.20)</u>	<u>0.47+/-</u> <u>0.24</u> <u>(0.12-</u> <u>0.98)</u>	<u>1.29+/-</u> <u>0.78</u> <u>(0.09-</u> <u>2.65)</u>	<u>0.58+/-</u> <u>0.83 (0-</u> <u>3.06)</u>	<u>1.45+/-</u> <u>0.91</u> <u>(0.09-</u> <u>3.06)</u>	<u>126.74+/-</u> <u>62.18</u> <u>(2-237)</u>	<u>47.19+/-</u> <u>44.62</u> <u>(0-118)</u>	<u>172+/-</u> <u>93.84</u> <u>(5-348)</u>

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<b>AIML -</b>	<u>0.49+/-</u> <u>0.21</u> <u>(0.11-</u> <u>0.96)</u>	<u>0.33+/-</u> <u>0.31</u> <u>(0-1.16)</u>	<u>0.48+/-</u> <u>0.22</u> <u>(0.11-</u> <u>0.96)</u>	<u>1.35+/-</u> <u>0.67</u> <u>(0.11-</u> <u>2.67)</u>	<u>0.74+/-</u> <u>0.9 (0-</u> <u>3.39)</u>	<u>1.49+/-</u> <u>0.87</u> <u>(0.11-</u> <u>3.39)</u>	<u>120.25+/-</u> <u>58.47</u> <u>(19-268)</u>	<u>45.35+/-</u> <u>43.19 (0-</u> <u>129)</u>	<u>169.97+/-</u> <u>88.72</u> <u>(21-381)</u>
<b>Mean Difference (%)</b>	<u>0.02 (5%)</u>	<u>0.06 (21%)</u>	<u>0.02 (3%)</u>	<u>0.06 (5%)</u>	<u>0.17 (29%)</u>	<u>0.04 (3%)</u>	<u>-6.49 (-5%)</u>	<u>-1.84 (-4%)</u>	<u>-2.07 (-1%)</u>
<b>p</b>	<u>0.06</u>	<u>&lt;0.01</u>	<u>0.09</u>	<u>0.07</u>	<u>&lt;0.01</u>	<u>0.25</u>	<u>0.09</u>	<u>0.33</u>	<u>0.58</u>

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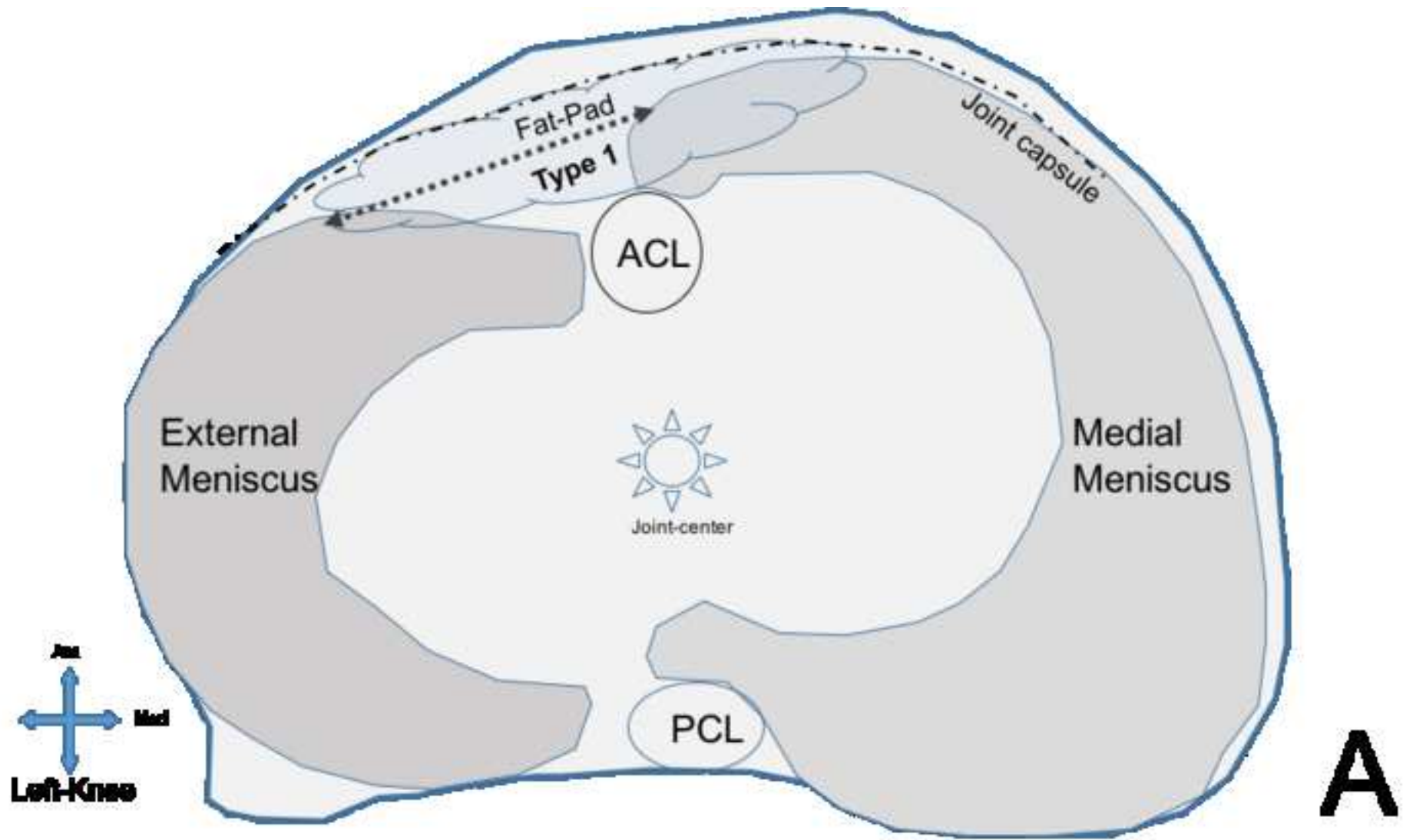
**Table 2. Results of 60° Flexion and 700N loading mechanical testing analysis.**

**AIML: intact anterior intermeniscal ligament**  
**AIML - : resected anterior intermeniscal ligament**

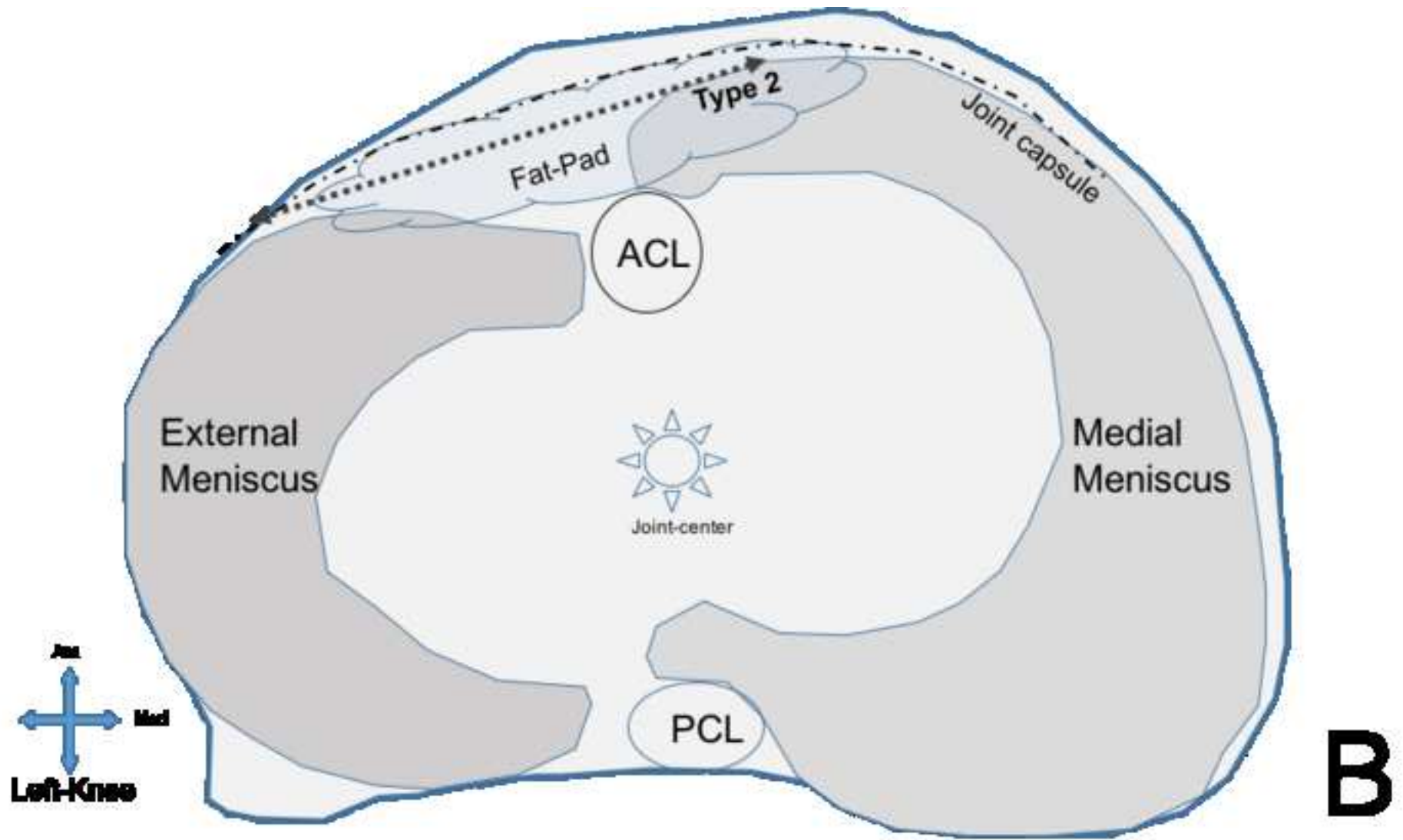
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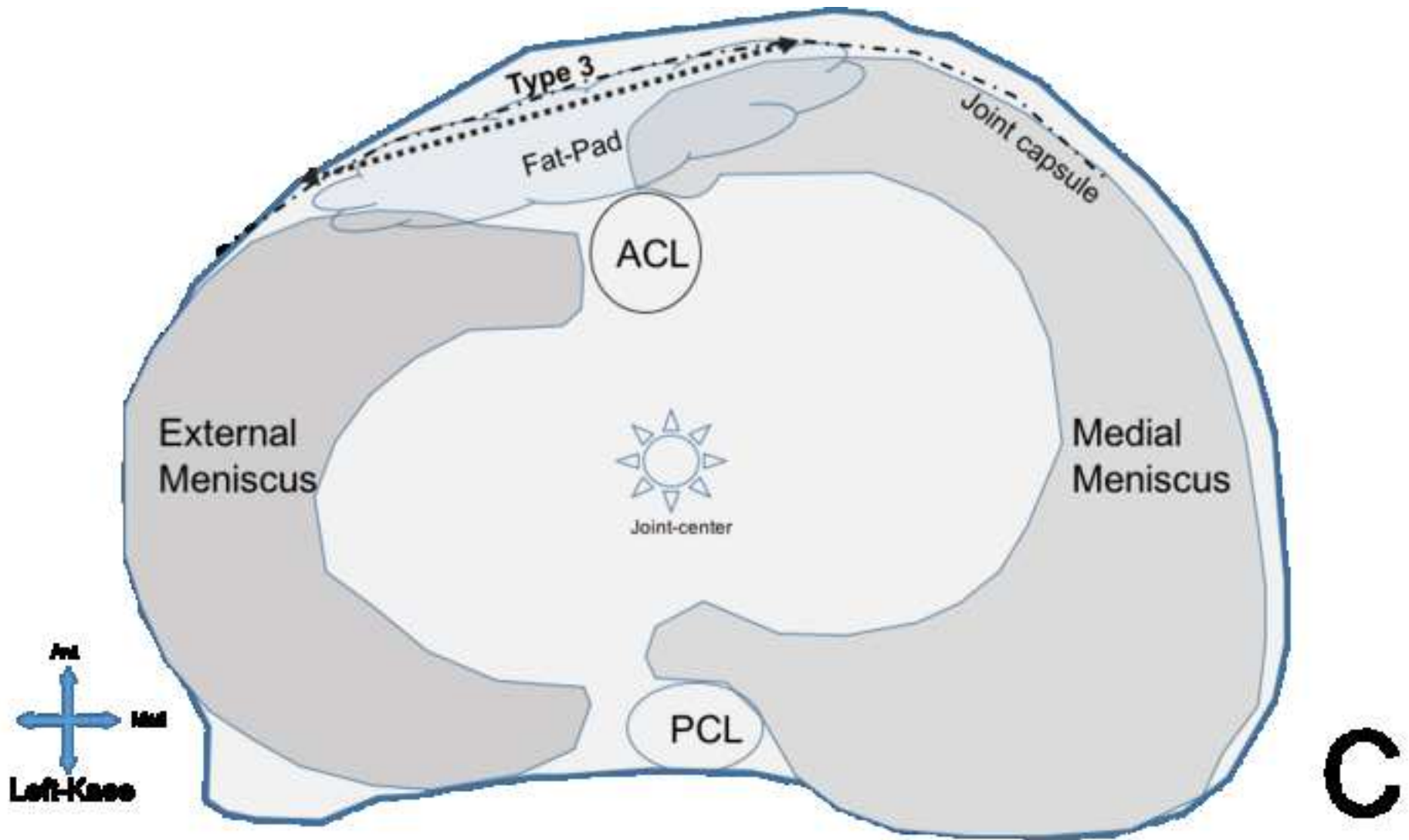
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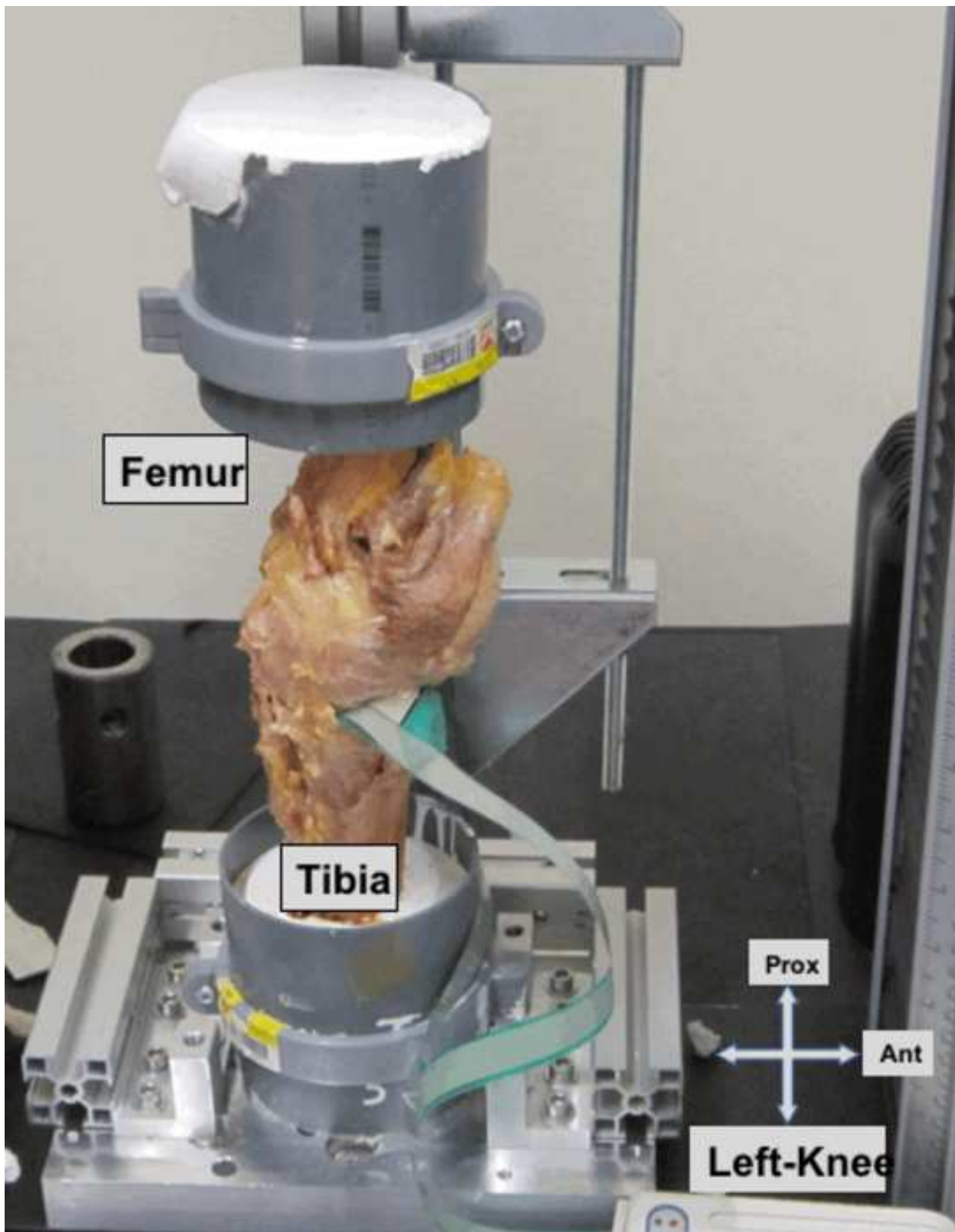
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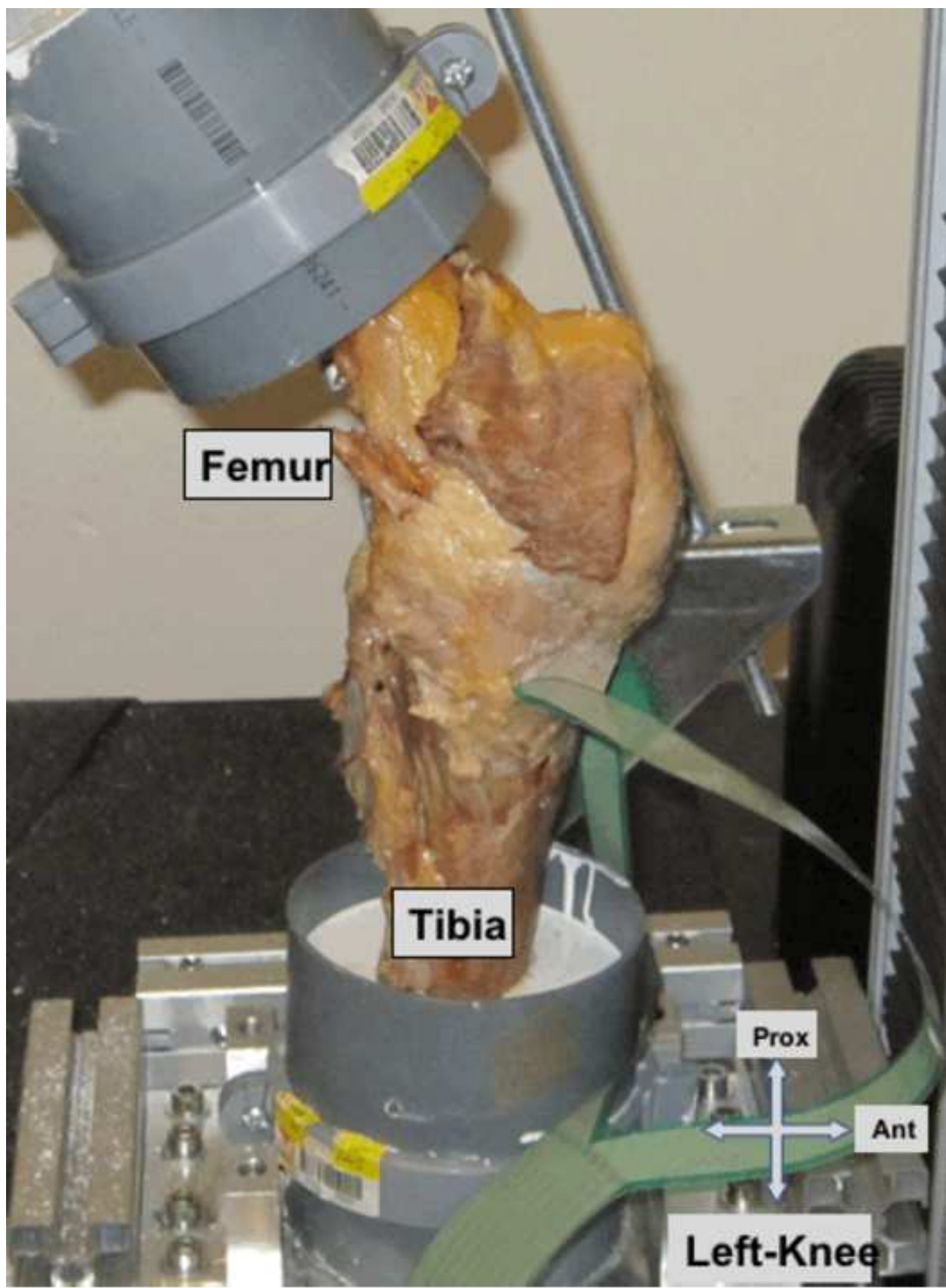






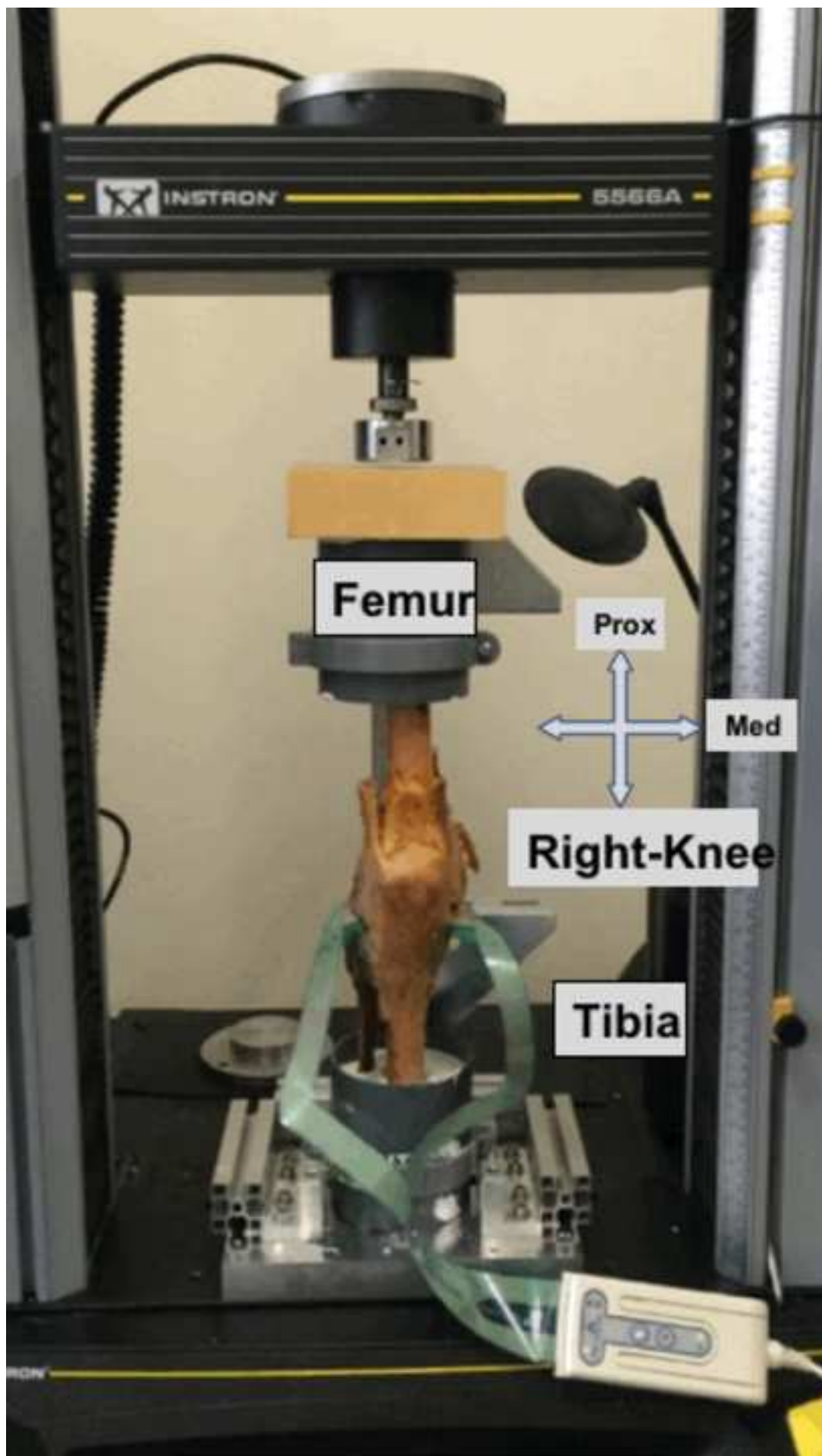


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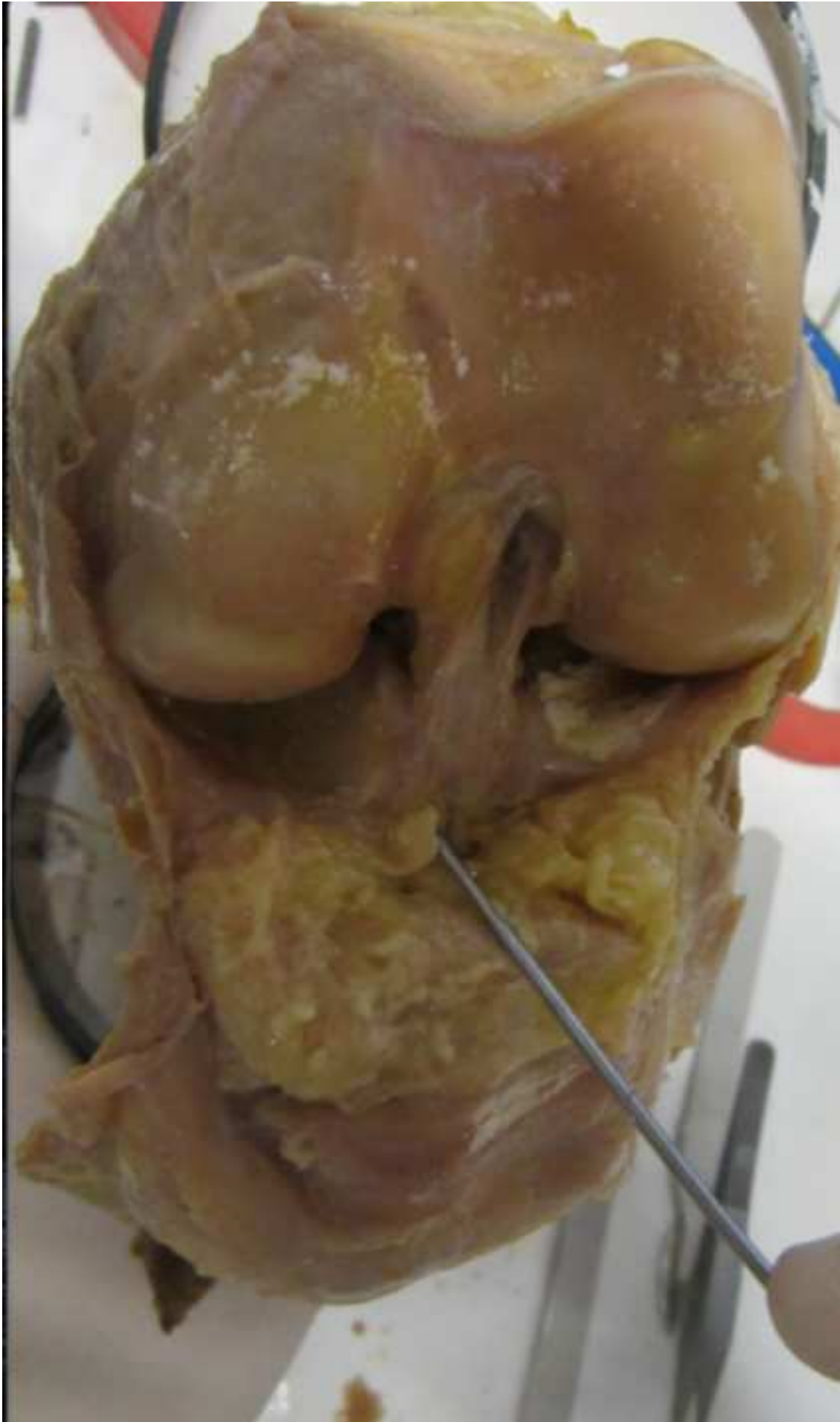




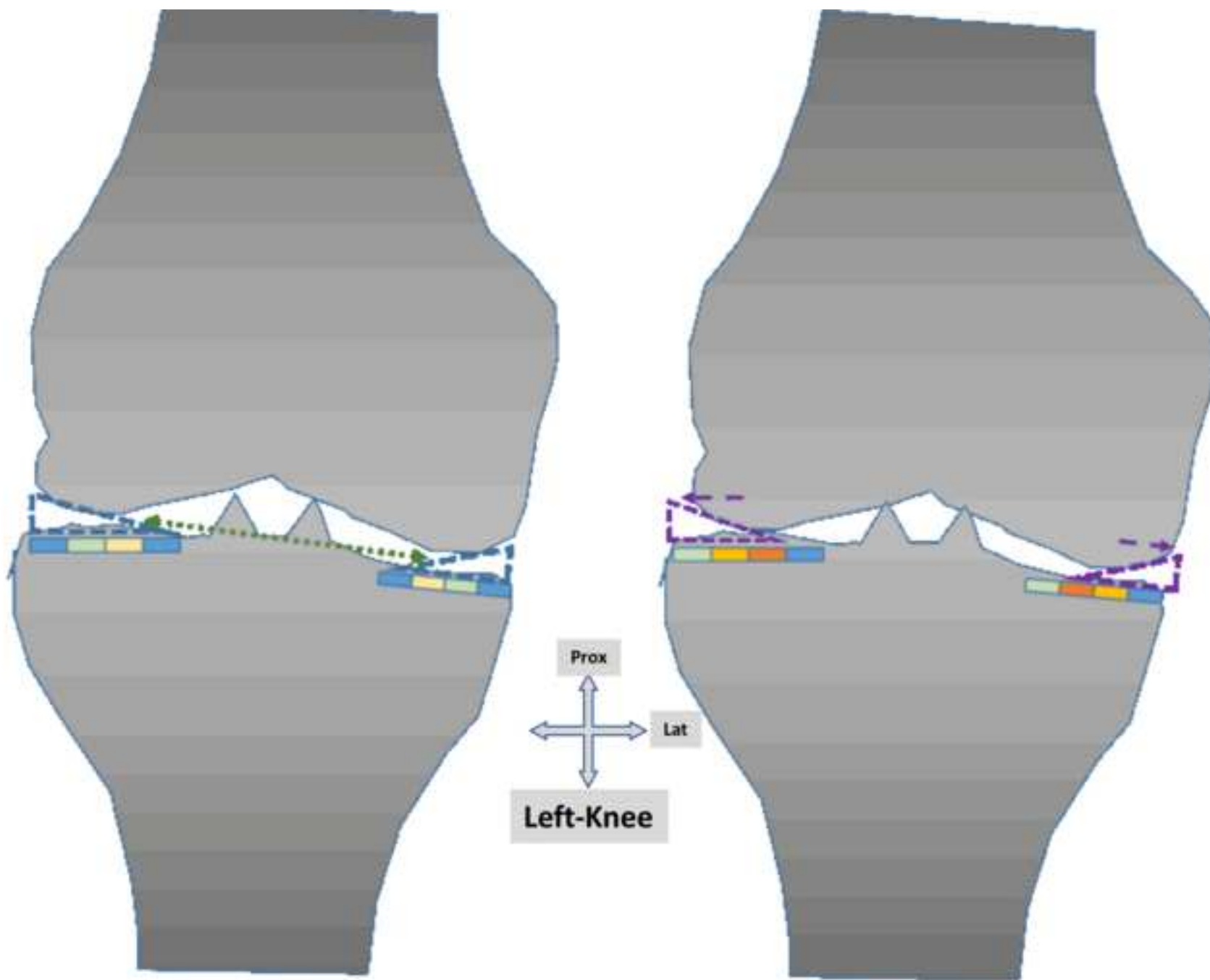
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## *Arthroscopy: The Journal of Arthroscopic and Related Surgery*

### — Instructions —

## ICMJE Form for Disclosure of Potential Conflicts of Interest

**Each author of the manuscript must separately complete and save this form using his or her name in the file name. Each author's completed form must then be uploaded with the manuscript.**

The purpose of this form is to provide readers of your manuscript with information about your other interests that could influence how they receive and understand your work. The form is in four parts:

### Section 1. Identifying information

Enter your full name and provide the manuscript title.

### Section 2. The work under consideration for publication

This section asks for information about the work that you have submitted for publication. The time frame for this reporting is that of the work itself, from the initial conception and planning to the present. The requested information is about resources that you received, either directly or indirectly (via your institution), to enable you to complete the work. Checking "No" means that you did the work without receiving any financial support from any third party — that is, the work was supported by funds from the same institution that pays your salary and that institution did not receive third-party funds with which to pay you. If you or your institution received funds from a third party to support the work, such as a government granting agency, charitable foundation, or commercial sponsor, check "Yes." Then complete the provide the information requested.

### Section 3. Relevant financial activities outside the submitted work

This section asks about your financial relationships with entities in the biomedical arena that could be perceived to influence, or that give the appearance of potentially influencing, what you wrote in the submitted work. You should disclose interactions with ANY entity that could be considered broadly relevant to the work.

Report all sources of revenue paid (or promised to be paid) directly to you or your institution on your behalf over the 36 months prior to submission of the work. This should include all monies from sources with relevance to the submitted work, not just monies from the entity that sponsored the research. Please note that your interactions with the work's sponsor that are outside the submitted work should also be listed here. If there is any question, it is usually better to disclose a relationship than not to do so.

For grants you have received for work outside the submitted work, you should disclose support ONLY from entities that could be perceived to be affected financially by the published work, such as entities or foundations supported by entities that could be perceived to have a financial stake in the outcome. Public funding sources, such as government agencies, charitable foundations, or academic institutions, need not be disclosed. For example, if a government agency sponsored a study in which you have been involved and drugs were provided by a pharmaceutical company, you need only list the pharmaceutical company.

### Section 4. Other relationships

Use this section to report other relationships or activities that readers could perceive to have influenced, or that give the appearance of potentially influencing, what you wrote in the submitted work.



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## Section 1. Identifying Information

1. Given Name Matthieu 2. Surname \_Ollivier
3. Are you the corresponding author? Yes \_
4. Effective Date \_\_\_\_10/1/2017
5. Manuscript Title

**The Anterior Intermeniscal ligament restrains menisci extrusion during knee loading.**

## Section 2. The Work Under Consideration for Publication

Did you or your institution at any time receive payment or services from a third party for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc...)?

Complete each item by typing an X in answer yes or not and completing the information requested if an answer is Yes. If you have more than one relationship, add lines.

### 1. Grant

Yes, money paid to to institution by SFA Comments (French-speaking arthroscopy society)

### 2. Consulting fee or honorarium

\_\_\_No

### 3. Support for travel to meetings for the study or other purposes

\_\_\_No \_\_\_

### 4. Fees for participation in review activities such as data monitoring boards, statistical analysis, end-point committees, and the like

\_\_\_No \_\_\_

### 5. Payment for writing or reviewing the manuscript

\_\_\_No \_\_\_

### 6. Provision of writing assistance, medicines, equipment, or administrative support

\_\_\_No \_\_\_

### 7. Other

\_\_\_No \_\_\_

### Section 3. Relevant financial activities outside the submitted work

1. Board membership

Yes, money paid to Philippe Beaufiles by OTSR\_\_\_ Comments (Editor)

2. Consultancy

Yes, money paid to Nicolas Pujol, Philippe Boisrenoult and Philippe Beaufiles by smith and nephew and Zimmer.

3. Employment

\_\_\_No \_\_\_

4. Expert testimony

\_\_\_No \_\_\_

5. Grants/grants pending

\_\_\_No \_\_\_

6. Payment for lectures including service on speakers bureaus

\_\_\_No \_\_\_

7. Payment for manuscript preparation

\_\_\_No \_\_\_

8. Patents (planned, pending or issued)

\_\_\_No \_\_\_

9. Royalties

\_\_\_No \_\_\_

10. Payment for development of educational presentations

\_\_\_No \_\_\_

11. Stock/stock options

\_\_\_No \_\_\_

12. Travel/accommodations/ meeting expenses unrelated to activities listed\*\*

\_\_\_No \_\_\_

13. Other (err on the side of full disclosure)

\_\_\_No \_\_\_

\*\* For example, if you report a consultancy above there is no need to report travel related to that consultancy on this line.



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## Answer to editorial and reviewers' queries

\* State who assessed the patients and their credentials.

Authors' response: it was a cadaveric study, in our anatomical lab, every specimen undergoes a full-body CT.

We then select for this study, specimens with minimal bone and joint degeneration.

Line 282 *ten unpaired...*

\* The purpose in the abstract and at the end of the introduction should be word for word the same. Please resolve the differences. The introduction version is more complete and descriptive.

Authors' response: done, we modified our abstract accordingly

Line 48 : *the aim (...)*

\* The conclusions in the abstract and at the end of the manuscript should be word for word the same. Please resolve the differences.

Authors' response: done, we modified our abstract accordingly

Line 117 : *the section (...)*

\* Figure Legends should identify the side of the body part.

Authors' response: done, we remade all of our figures to fulfil reviewers queries

Line 723 (*figures legend*)

\* Please update references with [Arthroscopyjournal.org](http://Arthroscopyjournal.org) advanced search

Done using Zotero line 563

\* The title describes meniscal extrusion, but this was not directly measured. It probably should be removed from the title.

Authors' response: done, we modified our title accordingly

Line 1 : *Sectioning of the anterior intermeniscal ligament changes knee loading mechanics.*

\* Should state any other structures that were resected or cut in order to insert the contact pressure measurement device.

Authors' response : done in our methods paragraph

Line 306 : *Anterior and posterior horizontal 3cm capsulotomies were made (splitting horizontally the anterior and superficial part of the medial collateral ligament and doing a sub-meniscal dissection on the lateral side) and sensors were inserted*

\* Line 237: It is best to avoid claims such as "the largest."

Authors' response : we switched for "a sufficient" line 517

\* Please add a Limitations heading and place this paragraph immediately before the Conclusions.

Authors' response : done, thanks for the time spent editing our paper.

Limitation paragraph starts line 473

\* ICMJE disclosure forms must be completed for each author. When all forms are complete, please combine all forms into a single PDF to upload as we are now publishing disclosure forms online as supplementary material when articles are published.

Authors' response : done

### Associate Editor's Comments:

#### 1. INTRODUCTION

This section should be arranged as follows: mechanical importance of menisci and meniscal belt. Anatomy of AIML.

Potential effects of AIML injury. Then state purpose and hypothesis.

Authors' response : done, thanks.

L 86-87: Matter of discussion. Please delete and discuss in the proper section.

Authors' response : done (deleted), thanks.

#### 2. METHODS

L 120-122: Is this a standardized procedure? If so, please add references.

Authors' response: we did follow Poh and al previously described method to prepare and insert the K-scan. The reference is inserted.

Line 300 : *Anterior and posterior horizontal 3cm capsulotomies were made (splitting horizontally the anterior and superficial part of the medial collateral ligament and doing a sub-meniscal dissection on the lateral side) and sensors were*

*inserted avoiding the anterior and posterior horns of the menisci, and the insertional ligaments below the two menisci following a previously described method*

L 132-141: This paragraph is rather confusing. Please revise.

Authors' response : we revised this paragraph thanks :

*Line 313 "Two series of analysis were planned : specimens in full extension (Figure 3) and 60° of flexion (Figure 3) to approximate heel strike and foot impulsion during the gait<sup>13</sup>. A standard compression load of 1400 N at a rate of 10 mm/min was applied to the knee in extension and held for 10 s, then after, positioning the knee a 60° flexion a standard compression load of 700 N at a rate of 10 mm/min was applied. Each specimens was re-tested after 15 min intervals to allow the knee to return to its unstressed state. The AIML was then sectioned with a surgical blade cutting through the fat-pad, and the two series of test were repeated. The 1400 N and 700N load were selected to approximate 1 and 2 time(s) body weight for an average 70 kg individual<sup>14</sup>."*

L 147-150: According to your sample size calculation, required sample size should be 27 for the medial meniscus and 20 for the lateral meniscus. Please verify.

Authors' response : we did verify, redo and confirm our calculation, we provide precision for this sample calculation (mean difference SD from Poh and al cited paper).

*Line 390 "Based on a previous research investigating on tibio-femoral contact pressure after AIML resection<sup>7</sup>, we designed our study to be able to detect > 10% variation of mean contact pressure below both medial and lateral meniscus ( $\Delta > 0.4 \pm 0.4$  MPa; baseline  $3.7 \pm 0.7$  MPa for the medial meniscus and  $1.9 \pm 0.6$  MPa for the lateral meniscus) with a statistical power of 80%. Both calculations are for a two-sided test with alpha of 0.05 and 1-Beta of 0.8."*

N.B : Poh and al paper is rather confusing for statistical sample size calculation (multiple testing with the same configuration ?) and using K-scan analysis offers plenty of data that can deeply modify statistical testing. We chose in our protocol to limit this, using only mean and maximal values more than true real time numbers (>3000 number for each configuration of testing and each parameters !!!): from poh et al : "for the outcome of mean contact pressure, post-hoc power analysis showed that a sample size of 15 measurements (five knees with three loadings each) has a power of 80% to detect a 10% increase or decrease ( $\Delta=0.27$  MPa) from a mean baseline of 2.73 MPa in the mean contact pressure of the medial and lateral compartment".

### 3. RESULTS

This section is well written.

Authors' response: thanks a lot

### 4. DISCUSSION

L 220-225: This paragraph should be reported earlier in the discussion section.

L 227-234: This paragraph should be reported earlier in the discussion section.

L 235-239: This paragraph should be reported earlier in the discussion section (before acknowledgment of limitations).

Authors' response: we redesigned our discussion line 422 to 525 changing position of the paragraph to fulfil those three queries

L 240-245: Clinical relevance of your hypothesis should be discussed more accurately. Is there clinical evidence of association between meniscal extrusion and AIML injury? If so, please describe previous reports and add references.

Authors' response: we did not find any clinical studies on the effect of AIML, at least one recent study discuss the interest of AIML reconstruction to limit menisci allograft extrusion, but we would rather not discuss this point as it is, in our mind, the same surgical/ anatomical configuration.

L 215: The effects of AIML on knee biomechanics can vary according to anatomic variants of AIML. Subgroup analysis on a larger sample size would be advisable. I would discuss on this as a limitation of your study.

Authors' response: we provided the following sentence

*Line 485 "More, the effects of AIML on knee biomechanics can vary according to anatomic variation. In this study, we did not perform MRI evaluation to assess specimens' anatomical positioning of the AIML. Thus, Subgroup analysis on a larger sample size would be advisable to obtain data regarding relationship between Nelson et Laprade<sup>5</sup> AIML insertion and potential effect on pressure parameters we evaluated in our protocol."*

### 5. CONCLUSIONS

L 253-254: Please delete.

Authors' response: done

### 6. ABSTRACT

L 29-30: Purpose statement in the abstract and in the intro must be identical. Please replace "research project" with "study" in both sections.

Authors' response: done, we modified our abstract accordingly

*Line 48 : the aim (...)*

L 51-53: Conclusions in the abstract and in the text must be identical.  
*Line 117 : the section (...)*

#### 7. CLINICAL RELEVANCE

Please consider replacing with L 253-254.

*Authors' response: done, we modified our abstract accordingly : Line 534*

#### 8. TITLE

Please clarify that this is a mechanical ex-vivo study.

*Authors' response: done, we modified our title to "Sectioning of the anterior intermeniscal ligament changes knee loading mechanics. An ex-vivo Mechanical Study". Line 1*

#### 9. FIGURES

Figure 1 is unclear. Please replace with 3 figures (numbered as figure parts) showing the 3 different attachment patterns.

*Authors' response : done. Thanks, to please other reviewers queries we also labeled the capsule and Hoffa fat pad, the dotted and dashed line.*

Figure 2 does not explain the experimental setup. Please replace with a line drawing.

*Authors' response: removed*

*Figures and legends have been modified as showed line 722*

#### 10. REFERENCES

See comments on L 120-122 / L 240-245.

*Authors' response: thanks*

#### 11. TABLES

Table 2 should report data of mechanical tests with the knees at 60 degrees of flexion. Please verify.

*Authors' response: we concur and we modified our table "subtitle".*

*Line 759*

#### **Reviewers' Comments:**

Reviewer #1:

Abstract:

-Line 30: "...during knee flexion" should be changed to "...in full extension and 60° of flexion."

*Authors' response: OK line 50.*

-Lines 31-38: Methods—please add within this section that the measurements were performed before and after resection of the AIML.

*Authors' response: done Line 58* "Two series of analysis were planned: before and after AIML resection, mechanical testing were performed with specimens in full extension and 60° of flexion to approximate heel strike and foot impulsion during the gait. A standard compression load of 1400 N at full extension and 700 N at 60° flexion was applied."

Line 51: "The section of the anterior intermeniscal ligament..."—add "anterior".

*Authors' response: Done line 58*

The conclusions should be identical with the manuscript's conclusions. Please revise it.

Authors' response: done *Line 117 : the section (...)*

Introduction:

-Line 96: "...during knee flexion"—please change to "...in full extension and 60° of flexion."

Authors' response: done line 172

-Lines 97-98: The hypothesis "...will lead to modified tibiofemoral contact areas and pressures..." needs to be more precise. Change "modified" to "increased" or "decreased".

Authors' response: done line 287-288

-Line 98: "...during knee movement"—please change to "...in full extension and 60° of flexion."

Authors' response: done line 288

Methods:

-Line 101: "Ten fresh frozen cadaveric knees..."—Please provide more information, such as right/left knees, paired or unpaired knees, in total n=10 or 10 paired knees?

Authors' response: answer provide line 292 here : "Ten unpaired fresh frozen cadaveric knees (6 right/ 4 left knees) were chosen out of the knees available at centre de Thanatopraxie de la Faculté de Médecine de Marseille".

-Lines 102-103: "Specimen selection..."—Could you give more precise inclusion and exclusion criteria for "macroscopic and radiographic inspection for bone and joint anomalies"? Which bone and joint anomalies were excluded? Did you also check for previous surgeries of the joint?

Authors' response: answer provided line 298 here: "specimens with substantial knee arthritis, bone deformities, scar or hardware related to previous surgery were excluded"

-Did you analyze the types of insertion according to Nelson and LaPrade (as mentioned within the Introduction and Figure 1) within the present study? If so, please provide the data within the Results section of the manuscript.

Authors' response: No we didn't. Nelson and LaPrade insertion checking would have probably conduced to a vast majority of type I and II insertion (thus, potential mechanical effect of type III are more complex to understand). Statistical analysis based on (estimation) 4 type I and 4 type II would have resulted in underpowered testing. We provided a paragraph in our discussion stating that those elements are key to understand AIML mechanical function.

Line 496 "More, the effects of AIML on knee biomechanics can vary according to anatomic variation. In this study, we did not perform MRI evaluation to assess specimens' anatomical positioning of the AIML. Thus, Subgroup analysis on a larger sample size would be advisable to obtain data regarding relationship between Nelson et Laprade<sup>5</sup> AIML insertion and potential effect on pressure parameters described in our results."

-Lines 114-116: Please give more details about the measurement accuracy of the K-scan sensor system for contact pressure and area. Which differences can this device distinguish?

Authors' response: K-scan sensors we used have a minimal spatial resolution of 0.62mm and a margin of error <3%, for pressure measurement those sensors have a minimal resolution of 0.01MPa (10KPa) with a margin of error depending on applied force (but within 2-7%). (data provided by the supplier but also found in cited papers, 9-10)

-Line 116: "Anterior and posterior horizontal capsulotomies..."—Please give more information about the exact location and extent of these capsulotomies. Did you perform these capsulotomies in a standardized fashion for all knees? Was it possible to close these capsulotomies (partially or fully) by suture before starting the measurements?

Authors' response: we did follow poh et al method, standard capsulotomies were performed to insert sensors, 3 cm capsulotomies were needed as the intra-articular part of the sensor was 2.8cm large.

Line 310 "Anterior and posterior horizontal 3cm capsulotomies were made (splitting horizontally the anterior and superficial part of the medial collateral ligament and doing a sub-meniscal dissection on the lateral side) and sensors were inserted avoiding the anterior and posterior horns of the menisci, and the insertional ligaments below the two menisci following a previously described method<sup>7</sup>."

-Line 118: Where did you exactly insert the pressure sensors? Which size was the sensor that was used in this study? Did you use one sensor for both sides (medial and lateral) or one sensor on each side?

Authors' response: we used tek-scan 4000 sensor (dedicated to knee joint research), it has two independent sensor that were inserted below each meniscus. The sensitive part of the sensor is a 2.8x3.3 cm square (<https://www.tekscan.com/products-solutions/pressure-mapping-sensors/4000>)

We do think that the new figure 2C provide clue to understand how sensors were used.

-Why did you not perform further measurements between 0° and 60° of flexion (for example, 0°, 20°, 40°, 60°)?

Authors' response: No we didn't.

60° flexion was the maximum load allowed by our mechanical protocol and we did not aim to investigate on dynamic range of motion. Keeping the sensor in the exact, same position during movement is quite impossible.

-Lines 129-131: Where did you cut through the patellar tendon? Please describe this more clearly for the reader.

Authors' response: we provided the following sentence

Line 329 : The AIML was then sectioned with an #11 surgical blade, starting 1 cm above joint line, cutting-down through the fat-pad until tibial bone contact, and the two series of test were repeated

-Line 130: "...through..."—spelling correction.

Authors' response : done line 330

-Did you perform a power analysis to check the needed number of knees for detecting differences between intact and resected AIML?

Authors' response : yes we did.

We provided clarification for this in our stats paragraph line 400

Results:

-Lines 155-156: Did you analyze the types of insertion according to Nelson and LaPrade (as mentioned within the Introduction and Figure 1) within the present study? If so, please provide the data.

Authors' response: No we didn't. Nelson and Laprade insertion checking would have probably conducted to a vast majority of type I and II insertion (thus, potential mechanical effect of type III are more complex to understand). Statistical analysis based on (estimation) 4 type I and 4 type II would have resulted in underpowered testing. We provided a paragraph in our discussion stating that those elements are key to understand AIML mechanical function.

Line 496 "More, the effects of AIML on knee biomechanics can vary according to anatomic variation. In this study, we did not perform MRI evaluation to assess specimens' anatomical positioning of the AIML. Thus, Subgroup analysis on a larger sample size would be advisable to obtain data regarding relationship between Nelson et Laprade<sup>5</sup> AIML insertion and potential effect on pressure parameters described in our results."

-Could you confirm a complete AIML resection in all dissected knees?

Authors' response ; Yes, as described line 400

-Line 165: "...at..."—spelling correction. Authors' response ; corrected line 424

-Line 167: "...internal meniscus..."—Please change to "medial meniscus". "... Was assessed individually"—please change to

"was assessed separately".

Authors' response ; done. Thanks. Line 426

Discussion:

-Line 178: "...by a meniscal extrusion..."—spelling correction.

Authors' response ; done. Thanks. Line 437

-Lines 180-181: "Our hypothesis..."—Please add this hypothesis (AIML resection will lead to menisci's extrusion) to the hypothesis in the Introduction session (Lines 97-98).

Authors' response ; As we cannot really conclude on extrusion we changed this sentence to :

Line 439 "Our hypothesis that intermeniscal ligament resection's lead to knee mechanical changes is verified by our model."

-Lines 189-197: The study design is quite similar with those of the study by Poh et al. Please point out more clearly the differences between the present study and the study of Poh et al. with respect to the Methods as well as the Results. In contrast to the results of the present study, Poh et al. concluded that an inadvertent sectioning of the AIML during surgery is insignificant. Please clarify and take a clear position with respect to that.

Authors' response ; We do think that we fairly compared our results to Paci et al and Poh et al papers :

Line 453 : Poh et al.<sup>7</sup> published in 2009 a study similar to ours, based on Tekscan analysis of 6 specimens loaded to 1800N at full extension, they reported a non-statistically significant variation after AIML resection regarding global contact pressure (2.73 to 2.84 MPa,  $p = 0.27$ ) and global contact-area (777 to 739 mm<sup>2</sup>,  $p = 0.06$ ). Their separate evaluation of the two menisci, demonstrated higher variation of mean contact pressure ( $\Delta=27\%$ ), peak contact pressure ( $\Delta=22\%$ ) and contact area ( $\Delta=13\%$ ) below the lateral meniscus. Those results are consistent with those reported in our study and even if their study was powered to detect 10% variations in mean contact pressure after AIML resection, their sample size was probably not sufficient to obtain adequate statistical power to evaluate the two menisci separately. Paci et al.<sup>15</sup> evaluated effect of AIML resection below the medial meniscus of 5 knees loaded to 1000N in five different position from 0 to 60 ° of flexion. They found a significant difference in terms of mean contact pressure from 20 to 50 ° with a maximum at 40° (3.68 to 4.69 MPa,  $\Delta=27.5\%$ ) but no significant difference at 0°, 10° and 60 ° flexion. In our study, we selected a lower load when our specimens were flexed to 60° (700N) to avoid specimens destruction related to a direct loading on fragile femoral diaphysis.

-Please point out more clearly what the present study adds as new and clinically relevant information to the recent literature.

-Please take a clear position if the results of the present study can be directly transferred to the clinical practice.

Authors' response ; As requested by the editor, we have modified our paragraph regarding clinical relevance of our findings.

Line 545 : "AIML resection performed ex-vivo in this study, might potentially be deleterious s in vivo. Clinical studies focusing on interest of preserving or even repairing the anterior intermeniscal ligament are needed to evaluate those ex-vivo elements."

-Lines 240-242: "Based on our hypothesis..."—Please add this hypothesis ("meniscus do not function as two separate entities but as a complex load-distributing system...") also to the hypothesis in the Introduction session (Lines 97-98). Please take a clear position to all hypotheses that were done.

Authors' response ; As requested by the editors, we removed this part of the sentence, our protocol aimed to investigate on potential effect of AIML resection, we cannot drive any conclusion on meniscus function or extrusion.

Thank you.

Conclusion:

The conclusions should be identical with the abstract's conclusions. Please revise.

Authors' response ; done. Thanks.

Title:

It is acceptable and concise.

Authors' response ; done. Thanks.

Appendix (figures, tables):

Authors' response ; We deeply modified figures and legends to fulfil all reviewers and editors queries. New figure and rename figures are now proposed. Line 736.

-Please revise the figures properly and provide more detailed information so that the reader can understand the figure more



easily and quickly.

-Figure 1: Right/left knee? Please label the capsule and Hoffa fat pad. Label also the dotted and dashed line.

Authors' response : done. Thanks.

-Figure 2: Provide more detailed explanations. Label the most important parts of the setting.

Authors' response : we removed figure 2 and provided more detailed information for new figures 2A and 2B (figure 3 and 4)

-Figure 3: Provide more detailed explanations. Label the most important parts of the setting, and clarify the tibial and femoral sides as well as the orientation of the knee (anterior-posterior, medial-lateral).

-Figure 4: Provide more detailed explanations. Label the most important parts of the setting, and clarify the tibial and femoral side as well as the orientation of the knee (anterior-posterior, medial-lateral).

Authors' response : Done , more detailed information for new figures 2A and 2B (figure 3 and 4)

Do you have an additional picture where the reader can see how the axial force is applied (larger field of view)?

Authors' response : new figure provided (figure 3)

-Figure 5: Right/left knee, medial-lateral—could you insert a magnification of the AIML showing the insertions?

Authors' response : we don't have this kind of picture, sorry.

-Figure 6: Right/left knee, medial-lateral—label and explain the dotted line as well as the color code.

Authors' response : done..

#### References:

Please update the references to the most recent literature of the last 5 years.

Authors' response ; done. Except one FEA study we did not find any recent paper to add...line 575

#### Reviewer #2:

##### Methods :

-Were any specimens excluded? Were there specific inclusion/exclusion criteria?

Authors' response ; Our selection process is first based on x-ray/CT evaluation of joint abnormalities/surgeries, we then select specimens from our anatomical collection to limit poor conservation issue and try to include specimens as "young" as possible to be clinically relevant. During this process, more than 100 specimens were screened and final selection was performed on more than 20 specimens with a careful macroscopic evaluation.

Line 292 to 297. Ten unpaired(...)

##### Results

Line 155: The author stated all specimens had a distinct AIML that was identified during dissection. Did the authors determine the type of AIML? It seems that a type I AIML would have a different effect on the meniscus with testing compared with a type III.

Authors' response: No we didn't. Nelson and Laprade insertion checking would have probably conducted to a vast majority of type I and II insertion (thus, potential mechanical effect of type III are more complex to understand). Statistical analysis based on (estimation) 4 type I and 4 type II would have resulted in underpowered testing. We provided a paragraph in our discussion stating that those elements are key to understand AIML mechanical function.

*Line 496 "More, the effects of AIML on knee biomechanics can vary according to anatomic variation. In this study, we did not perform MRI evaluation to assess specimens' anatomical positioning of the AIML. Thus, Subgroup analysis on a larger sample size would be advisable to obtain data regarding relationship between Nelson et Laprade<sup>5</sup> AIML insertion and potential effect on pressure parameters described in our results."*

-The clinical relevance sentence should be changed to match that of the conclusion in the manuscript. The sentence in the abstract is overly stated. It should be modified.

Authors' response ; done. Thanks. Line 546.

##### Title

-The title could be more descriptive.

-I suggest "Sectioning of the anterior intermeniscal ligament changes knee loading mechanics".

Authors' response ; modified, thanks. Line 1

##### Figures

-Figure 2 is unnecessary.

-Figures 3 and 4 should be combined to Figures 3A and 3B.

Authors' response : Done thanks. Line 739

##### References

References are appropriate.

Authors' response ; thanks.

Tables

The tables clearly demonstrate the results and data collected for the study.

Authors' response ; thanks.