

# Uncommon Complications after Anterior Cruciate Ligament Reconstruction

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## Abstract

Anterior cruciate ligament reconstruction (ACL-R) is a common surgical procedure, with good outcome in 75 to 97% of the cases. However, different complications have been described including infection, hemarthrosis, deep vein thrombosis (DVT), and pulmonary embolism (PE) with a rate ranging from 1 to 15%. There are few case reports in the literature describing rare complications after ACL-R and they can be divided into: (1) complications related to the fixation device (rupture, migration); (2) fractures (tibial or femoral side); (3) infections due to uncommon bacteria, mycobacterium, and mycosis; (4) rare vascular injuries; (5) nerve injuries; and (6) other rare complications. In case of fixation device rupture or migration, device removal can be easy but the diagnosis may be challenging. Patellar fracture after ACL-R may be related to harvesting and it is not uncommon. Conversely, femoral or tibial fractures are most frequently due to bone weakness related to bone tunnels. Some rare infections related to uncommon bacteria or mycosis are also described with potentially devastating joint damage. Popliteal artery injuries are uncommon in ACL-R but minor vessels damages are described with possible severe consequences for patients. Injuries to the infrapatellar branch of the saphenous nerve are not uncommon in ACL-R. However, there are few case reports also describing injuries to the saphenous nerve, the common peroneal nerve and the sciatic nerve. The aim of this paper is to review the literature describing uncommon complications after ACL-R, giving some more information about diagnosis and treatment.

## Keywords

- complication
- rare
- uncommon
- anterior cruciate ligament
- reconstruction

## Introduction

Anterior cruciate ligament reconstruction (ACL-R) is a very common surgical procedure, with more than 120,000 surgeries performed annually in the United States.<sup>1</sup> Different studies reported good outcomes after ACL-R with a return to preinjury level of activity ranging from 75 to 97%.<sup>2–4</sup> However, a failure rate ranging from 10 to 15% and a complication rate

ranging from 1 to 15% are also reported.<sup>5,6</sup> Complications after ACL-R, such as deep vein thrombosis (DVT), hemarthrosis, effusion and synovitis, infection, or arthrofibrosis are not uncommon.<sup>7</sup> DVT and pulmonary embolism (PE) are relatively rare complications following ACL-R but the incidence of asymptomatic DVT is reported to be closed to 15%.<sup>8</sup> Other studies described a 90-day PE rate of 0.08% and 90-day DVT rate of 0.12% in 301,701 elective arthroscopic procedures.<sup>9</sup>

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Knee joint infection is a rare but potentially devastating complication after ACL-R, with an incidence ranging from 0.14 to 1.70%.<sup>10-12</sup> Graft choice may be associated to the risk of infection with a reported increased risk for hamstring compared with bone-patellar tendon-bone (BPTB) autograft and for allograft compared with autograft.<sup>13-16</sup>

During graft harvesting, different possible complications may occur, such as patellar fracture, with an incidence ranging between 0.2 and 2.3% during BPTB graft harvesting.<sup>17</sup> Similarly, hamstring graft harvesting may be related to different complications, such as the risk to cut the tendons at an undesirably short length. This complication typically occurs when fascial bands are not sufficiently freed off the tendons, forcing the stripper to prematurely amputate the tissue.<sup>18</sup> Another common complication after ACL-R is postoperative hemarthrosis but it can be avoided using a postoperative drain for 24 hours. McCormack et al found that the hemarthrosis score was statistically smaller 1 week after surgery in the drained group ( $p = 0.02$ ) compared with the notdrained one but this difference was no more relevant after 4 or 8 weeks.<sup>19</sup>

Despite the amount of literature regarding common complications following ACL-R, there are few case reports describing uncommon complications. These complications may be divided into six categories: (1) complications related to the fixation devices (rupture or migration); (2) fractures (on tibial or femoral side); (3) infection due to uncommon bacteria and mycosis; (4) rare vascular injuries; (5) nerve injuries; and (6) others complications. The aim of this literature review is to describe diagnosis and treatment of these uncommon complications following ACL-R.

## Complications Related to the Fixation Devices

The fixation devices used in ACL-R can be divided (based on the type of fixation) into suspension, transfixion or expansion, and compression.

Within the compression devices, metallic or absorbable interference screws are the most commonly used for both soft tissue and BPTB grafts. Theoretical advantages of absorbable compared with metallic screws are lower risk of graft injury during fixation, less difficulties during revision surgeries and low interference during magnetic resonance imaging (MRI). Different disadvantages are also described, such as synovitis related to screw absorption, osteolysis around the screw, chronic effusion, and aseptic exudates.<sup>20</sup> However, a recent Cochrane review did not demonstrate any differences in self-reported outcomes, postoperative activity level, implant breakage during surgery and major postoperative complications between metallic or absorbable interference screws.<sup>21</sup>

Different complications have been described using both absorbable and metallic interference screws for graft fixation. Screw breakage during insertion has been described to be more frequent using absorbable compared with metallic screws, with a rate closed to 10%. Different authors concluded about no association between screw breakage and

worse clinical outcome but it may be associated to low primary stability.<sup>22</sup> Late screw breakage after ACL-R is a rare complication. There are four case reports in literature describing five cases of late absorbable interference screw breakage on the tibial side.<sup>23-26</sup> In all the cases, the breakage occurred within 1 year after surgery. All patients had minor trauma, such as standing up from a chair, or no trauma. Patients experienced persistent swelling and mechanical symptoms, such as locking or popping. In all the cases an MRI was performed, confirming an intra-articular loose body. All the patients underwent arthroscopic screw removal and in all the cases the screw was located in the intercondylar notch. In one case, the broken screw caused a cartilage damage on the patellar side. In all the cases the symptoms resolved after screw removal and patients completely recovered.<sup>23-26</sup> Loosening and intra-articular migration of interference screws after ACL-R are also a rare but possible complication, requiring screw removal because of mechanical problems and cartilage damages. Screw migration may be related to a tunnel-screw size mismatch, screw divergence, poor bone quality, tunnel enlargement, or bone resorption due to thermal necrosis during tunnel drilling.<sup>27,28</sup> Bone tunnels enlargement may be associated to graft-tunnel interface micromotion, accelerated rehabilitation, improper graft fixation or placement, presence of allograft, graft swelling and the so-called "pressure-effect".<sup>29</sup> There are four papers in literature describing five cases of tibial interference screw migration.<sup>28,30-32</sup> In three cases the migration occurred within 1 year from the ACL-R,<sup>30,31</sup> while in the last two cases it occurred 1 and 2 years after the surgery.<sup>28,32</sup> Hamstring graft was used in four cases,<sup>30-32</sup> while BPTB graft was used in the remaining one.<sup>28</sup> In four cases an intra-articular migration occurred,<sup>28,30,31</sup> and in the last one the screw migrated extra-articularly and it was palpable under the skin of the proximal tibia.<sup>32</sup> Screw migration may have different clinical presentations, such as mechanical symptoms,<sup>28,31</sup> erythema, palpable mass, wound dehiscence,<sup>32</sup> effusion, and limited range of motion (ROM).<sup>30</sup> MRI was performed in all the cases to diagnose screw migration.<sup>28,30-32</sup> Patients underwent arthroscopic device removal and in one case a posteromedial portal was required to remove the screw.<sup>28</sup> In most of the patients, symptoms disappeared after device removal but one patient complained about a residual instability and a limited ROM.<sup>30</sup>

Transfixion devices, such as cross-pins, may also be used for ACL graft fixation. Some authors preferred absorbable device instead of metallic ones, because of their potential, such as graft irritation, problems during revision procedures, as well as MRI distortion.<sup>33</sup> Three case reports reporting cross-pin breakage were described in literature.<sup>34-36</sup> The same fixation device was used in all the cases (RigidFix, Mitek) and a late breakage occurred with patients complaining about sudden effusion, pain, and catching sensation.<sup>34-36</sup> In two cases an MRI was performed but it was not determinant to assess device breakage.<sup>34,35</sup> All the cases underwent a diagnostic arthroscopy. In one case the broken device was found in the lateral compartment with associated lateral

chondral damage.<sup>35</sup> In the second case, the device was found in the posterolateral corner, lodged in the popliteal hiatus,<sup>34</sup> while in the last case the device was found in the medial compartment with associated chondral damage.<sup>36</sup> In all the cases, there were no graft damages and the patients completely recovered after device removal.<sup>34–36</sup>

There are three case reports in literature describing a cortical button migration. In the first case, the button was found in the popliteal space 25 months after surgery and it was arthroscopically removed.<sup>37</sup> In the second case, the cortical button was found in the knee joint at the 2 years follow-up X-ray. The patient was completely asymptomatic and refused arthroscopic device removal.<sup>38</sup> In the last case, the patient sustained ACL rerupture 3 years after the primary reconstruction and the X-rays showed intra-articular displacement of the cortical button. The patient underwent an ACL-R revision with button removal. Intraoperatively, it was noted that the femoral tunnel exit was too anterior in the suprapatellar pouch, with suture loop failure and consequent intra-articular displacement of the cortical button.<sup>39</sup>

► **Table 1** summarizes these cases.

## Rare Fractures

Patellar fracture may occur during BPTB autograft harvesting. Studies have reported the incidence of intraoperative and postoperative patella fractures with BPTB graft ranging between 0.2 and 2.3%.<sup>40</sup> Tibial and femoral fractures are less common compared with patellar fractures.

### Tibial Fracture

Tibial fracture is a rare complication following ACL-R. Different factors may be related to increased risk for tibial fracture after ACL-R. Biomechanical studies found that bone defects, for example, due to bony tunnel for an ACL-R may decrease bone strength to torsional loading. Moreover, drill holes may cause a reduction of 20% of the mineral bone density, reducing the bone strength from 55 to 90%.<sup>41</sup> Other authors described a possible association between tunnel enlargement and risk of fracture development.<sup>29,42</sup> Furthermore, other authors reported an increased risk of tibial fracture if a BPTB graft was used, probably due to the increased stress related to both presence of a tibial defect (for graft harvesting) and the tibial tunnel.<sup>43</sup> There are 17 case reports in literature describing tibial fracture after ACL-R.<sup>43–58</sup> However, five case reports were excluded from this review because the fracture was due to a high energy trauma (traffic accident).<sup>51–55</sup> Furthermore, one case report was excluded because it was written in German language<sup>56</sup> and one other because it was poorly described.<sup>57</sup> Moen et al described a proximal tibial fracture at the graft harvesting site due to stress concentration at this location. The patients underwent conservative treatment in a long leg cast and completely recovered from the complication.<sup>50</sup> In the remaining nine reports, the BPTB graft was used in five cases,<sup>43,45–47</sup> while soft tissue graft was used in four cases.<sup>10,48,49,58</sup> In most of the cases the fracture occurred within 6 months from the ACL-R.<sup>44,58</sup> However, in one case it occurred 4.5 years after surgery due to a minor trauma in a

40 years old man.<sup>10</sup> Fractures occurred at the tibial tunnel in three cases<sup>10,48,49</sup> and at the harvesting site in four cases.<sup>44–46,58</sup> In one case, the fracture begun from the transosseous tunnel and involved the entire tibial plateau.<sup>43</sup> In the remaining case, the fracture occurred at the graft fixation site at the tibial side.<sup>47</sup> All patients presented complaining about swelling, hemarthrosis, and inability to bear weight. In seven cases, the fracture was diagnosed with an X-ray<sup>43–46,48,58</sup> and in seven cases, a computed tomography (CT) scan was obtained to better evaluate fracture morphology<sup>43–45,47,48,58</sup>. In one case the undisplaced tibial plateau fracture was not detected with X-rays and an MRI was necessary to confirm the diagnosis.<sup>49</sup> Three cases were surgically managed with open reduction and internal fixation,<sup>10,45,46</sup> one case was surgically treated with a minimally invasive surgical technique using screws.<sup>43</sup> In all these cases the fracture was displaced. The remaining five cases with an undisplaced fracture were treated with no weight-bearing and cast or brace for 4 to 6 weeks<sup>44,47–49</sup>. In seven cases, patients completely recovered from the complication<sup>10,44–47,58</sup> but in the remaining two cases, patients complained about postoperative mild decreased ROM.<sup>43,49</sup> ► **Table 2** summarized all the case reports previously described.

### Femoral Fracture

Femoral fracture following ACL-R is a rare but devastating complication and it was mostly due to technical errors or to the creation of additional bone holes for supplemental fixation devices. Different authors described a decreased bone mineral density up to 20% following knee ligament injury that may be involved in the development of femoral fractures during or after ACL-R.<sup>59</sup> In most of the case reports of femoral fracture after ACL-R, an extra-articular fixation with a 6.5 mm screw,<sup>60</sup> staple,<sup>61</sup> cross-pin,<sup>62–65</sup> or additional removal of a 6.5 mm transverse cancellous screw<sup>66</sup> were related to this complication. Other authors reported multiple cortical passes with the guide pin<sup>67,68</sup> or drilling for screw placement<sup>60</sup> as possible risk factor associated for fracture development. Furthermore, tunnel malpositioning with posterior wall blow-out,<sup>69</sup> vertical tunnel placement,<sup>68–70</sup> tunnel widening,<sup>71</sup> and the presence of multiple femoral tunnels in revision ACL-R<sup>72</sup> are other possible factors related to femoral fractures. Some authors suggested an increased risk for fracture with femoral tunnel greater than 10 mm of diameter.<sup>61</sup> Han et al in their biomechanical study evaluated the possible role of the femoral tunnel as potential stress riser associated with fractures, comparing the risk for fracture between single bundle (SB) and double bundle (DB) techniques. The authors concluded that an anatomic independently drilled single bundle femoral tunnel, whether a BPTB or hamstring graft is used, is not a stress riser for femoral fracture. In their experimental model, there was a significant difference in load to failure in the DB group compared with the SB group. Furthermore, the fracture patterns of the DB group always occurred through both femoral tunnels at the notch, whereas the SB groups had similar fracture patterns throughout the lateral cortex and not always involving the femoral tunnel.<sup>59</sup> Although the

**Table 1** Rupture of bio-absorbable screw and cross-pin and the migration of the devices

Authors	Age (y) and gender	Type of graft and type of fixation system	Timing (months)	Diagnosis and symptoms	Treatment	Note
Muneta et al <sup>37</sup> (1999)	-	<ul style="list-style-type: none"> <li>Cortical button</li> </ul>	25	<ul style="list-style-type: none"> <li>MRI</li> </ul>	Arthroscopy	
Bottoni et al <sup>31</sup> (2000)	44 and male	<ul style="list-style-type: none"> <li>Hamstring</li> <li>Absorbable screw</li> </ul>	7	<ul style="list-style-type: none"> <li>MRI</li> <li>Similar to meniscal lesion</li> </ul>	Arthroscopy	
Sassmannshausen and Carr <sup>32</sup> (2003)	28 and female	<ul style="list-style-type: none"> <li>Hamstring</li> <li>Absorbable screw</li> </ul>	12	<ul style="list-style-type: none"> <li>X-Rays</li> <li>Erythema, palpable mass, wound dehiscence</li> </ul>	Arthroscopy	Extra-articular migration
Yanmiş et al <sup>38</sup> (2004)	28 and male	<ul style="list-style-type: none"> <li>Anterior tibial tendon allograft</li> <li>Cortical button</li> </ul>	24	<ul style="list-style-type: none"> <li>Asymptomatic</li> </ul>	No treatment	
Cosseyand Paterson <sup>36</sup> (2005)	23 and male	<ul style="list-style-type: none"> <li>Patellar bone-tendon-bone graft</li> </ul>	13	<ul style="list-style-type: none"> <li>Intermittent episodes of locking</li> </ul>	Arthroscopy	
Lembeck and Wülker <sup>23</sup> (2005)	27 and female	<ul style="list-style-type: none"> <li>BPTB</li> <li>Absorbable screw</li> </ul>	12	<ul style="list-style-type: none"> <li>MRI</li> <li>Persistent swelling and intermittent locking</li> </ul>	Arthroscopy	
Resinger et al <sup>28</sup> (2005)	23 and female	<ul style="list-style-type: none"> <li>BPTB</li> <li>Absorbable screw</li> </ul>	48	<ul style="list-style-type: none"> <li>MRI</li> <li>Locking and pain in the popliteal fossa</li> </ul>	Arthroscopy	Posteromedial arthroscopic portal
Han et al <sup>34</sup> (2005)	18 and male	<ul style="list-style-type: none"> <li>Allogenic semitendinosus-gracilis graft</li> <li>Absorbable pins</li> </ul>	14	<ul style="list-style-type: none"> <li>X-Ray and MRI (not diagnostic)</li> <li>Sudden, migrant, painful, catching sensation during extension</li> </ul>	Arthroscopy	
Bollen and Hoeven <sup>24</sup> (2006)	19 and female	<ul style="list-style-type: none"> <li>Semitendinosus-gracilis graft</li> <li>Absorbable screw</li> </ul>	7	<ul style="list-style-type: none"> <li>MRI</li> <li>Pain, swelling, and minor extensor deficit</li> </ul>	Arthroscopy	
Bollen and Hoeven <sup>24</sup> (2006)	17 and female	<ul style="list-style-type: none"> <li>Semitendinosus-gracilis graft</li> <li>Absorbable screw</li> </ul>	12	<ul style="list-style-type: none"> <li>MRI</li> <li>Pain</li> </ul>	Arthroscopy	
Krappel et al <sup>30</sup> (2006)	40 and male 37 and male	<ul style="list-style-type: none"> <li>Hamstring</li> <li>Absorbable screw</li> <li>•••</li> <li>Hamstring</li> <li>Absorbable screw</li> </ul>	34	<ul style="list-style-type: none"> <li>MRI in both of cases</li> <li>Mimics infection with effusion and limited ROM</li> <li>Pain, swelling, effusion and locking episodes</li> </ul>	Arthroscopy in both of cases	<ul style="list-style-type: none"> <li>Failure of the graft</li> <li>Full recovery</li> </ul>
Metcalfe et al <sup>26</sup> (2008)	-	<ul style="list-style-type: none"> <li>Semitendinosus-gracilis graft</li> <li>Absorbable screw</li> </ul>	2	<ul style="list-style-type: none"> <li>X-Ray</li> <li>Acute effusion and locking knee at 20 degrees of flexion</li> </ul>	Arthroscopy	
Papastergiou et al <sup>35</sup> (2009)	20 and male	<ul style="list-style-type: none"> <li>Semitendinosus-gracilis graft</li> <li>Absorbable pins</li> </ul>	20	<ul style="list-style-type: none"> <li>MRI (not diagnostic)</li> <li>Effusion and lateral joint-line pain</li> </ul>	Arthroscopy	

(Continued)

**Table 1** (Continued)

Authors	Age (y) and gender	Type of graft and type of fixation system	Timing (months)	Diagnosis and symptoms	Treatment	Note
Huang and Tan <sup>25</sup> (2012)	22 and female	<ul style="list-style-type: none"> <li>Semitendinosus-gracilis graft</li> <li>Absorbable screw</li> </ul>	6	<ul style="list-style-type: none"> <li>MRI</li> <li>Pain and locking with an extension deficit of 5 degrees</li> </ul>	Arthroscopy	
Ho and Lee <sup>39</sup> (2017)	24 and male	<ul style="list-style-type: none"> <li>Cortical button</li> </ul>	36	<ul style="list-style-type: none"> <li>ACL rerupture</li> </ul>	ACL-R and button removal (arthroscopic)	

Abbreviations: ACL, anterior cruciate ligament; ACL-R, ACL-reconstruction; BPTB, bone-patellar tendon-bone; MRI, magnetic resonance imaging; ROM, range of motion.

incidence of femoral fracture due to ACL-R is unknown, it is suspected to be extremely low.<sup>73</sup> There were 13 case reports of femoral fractures after ACL-R in literature including 14 patients. Four papers were excluded because of additional surgical procedure (i.e., lateral tenodesis or multiple ligament reconstruction),<sup>42,60</sup> high energy trauma related to the fracture<sup>53</sup> or because complete data for analysis were not available.<sup>63</sup> In the remaining studies, the fractures occurred in a period ranging from 2 months to 7 years, with one intra-operative fracture.<sup>74</sup> The case described by Downen et al deserves an aside discussion. The fracture occurred 7 years after ACL-R on a tumor mass located in the femoral tunnel. The pathological fracture was related to a lytic lesion causing a femoral tunnel enlargement. The mass biopsy confirmed the diagnosis of bone giant cell tumor. The treatment included wide mass debridement, screw removal, and defect filling with polymethyl methacrylate bone cement. Open reduction and internal fixation was then performed to stabilize the fracture.<sup>75</sup> Different grafts were used in the other case reports: gore-tex graft was used in one case,<sup>70</sup> BPTB graft was chosen in four cases,<sup>29,68,69,71</sup> and hamstring graft was used in the remaining cases.<sup>61,62,64,66,67,75,76</sup> In most of the cases the fracture was due to a low energy trauma, such as knee twisting<sup>64,70,71,76</sup> and light fall.<sup>29,61,69</sup> In four cases a stress fracture was described.<sup>62,66,68</sup> In the last report, the fracture was due to an over-reaming of a previous tunnel in a revision ACL-R. The stress of the reamer to enlarge the previous tunnel caused a coronal fracture in the lateral condyle. The treatment was planned in two stages: first the fracture was treated, then once it was healed, the ACL-R revision was performed.<sup>74</sup> Clinical presentation was similar in all the cases, with pain and impossible weight-bearing on the affected knee. In all the cases X-Rays and CT scans were performed. Two cases were treated conservatively with complete recovery.<sup>62</sup> Surgical treatment was performed in the remaining cases, with different strategies for fixation, depending on the fracture morphology. Internal fixation with intramedullary nail was performed in three cases with one good outcome,<sup>71</sup> one case of postoperative ROM reduction<sup>68</sup> and one case of mild instability.<sup>66</sup> Four cases were treated with screws with complete recovery<sup>29,61,64</sup>. In one case there was a fracture displacement 3 months after screws fixation. A second surgical procedure was performed and the fracture was treated using bone grafting and refixation. Despite this second surgery, the presence of a persistent nonunion required a third surgical procedure and the fracture was fixed with a plate. The fracture eventually healed, the knee was stable but the patient complained about a loss of ROM.<sup>69</sup> In the remaining cases open reduction and internal fixation with plate and screws was performed with good outcomes.<sup>67,70,74,76</sup> **Table 3** summarized the case reports previously described.

**Uncommon Infections**

Septic arthritis after ACL-R is a relatively rare but serious complication, associated to high rate of reoperations, need for prolonged antibiotic therapy, graft removal, and delayed

**Table 2** Summary of case reports describing tibial fracture after ACL-R

Authors	Age (y) and gender	Type of fracture and graft	Type of trauma and presentation and timing	Imaging	Treatment (T) and outcome (O)
Mithöfer et al <sup>43</sup> (2004)	61 and female	<ul style="list-style-type: none"> <li>Medial and lateral tibial plateau</li> <li>BPTB</li> </ul>	<ul style="list-style-type: none"> <li>Fall</li> <li>Pain, swelling, inability to weight-bearing</li> <li>7 mo</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: minimally invasive surgery fixation</li> <li>O: mild decrease of ROM</li> </ul>
Sundaram et al <sup>49</sup> (2006)	40 and female	<ul style="list-style-type: none"> <li>Tibial plateau fracture extending to the tunnel</li> <li>Hamstring</li> </ul>	<ul style="list-style-type: none"> <li>Fall</li> <li>Pain, swelling, hemarthrosis</li> <li>12 mo</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays (not detect the fracture)</li> <li>MRI</li> </ul>	<ul style="list-style-type: none"> <li>T: conservative with cast and knee brace</li> <li>O: mild decrease of ROM</li> </ul>
Thaunat et al <sup>47</sup> (2006)	24 and male	<ul style="list-style-type: none"> <li>Tibial fixation site</li> <li>BPTB</li> </ul>	<ul style="list-style-type: none"> <li>Fall (1 mo of high)</li> <li>Pain, inability to weight-bearing, hemarthrosis</li> <li>4 y</li> </ul>	<ul style="list-style-type: none"> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: conservative with cast and knee brace</li> <li>O: full recovery</li> </ul>
Voos et al <sup>45</sup> (2008)	43 and female	<ul style="list-style-type: none"> <li>Metaphyseal tibial fracture extending to donor site</li> <li>BPTB</li> </ul>	<ul style="list-style-type: none"> <li>During jogging</li> <li>Pain, swelling</li> <li>4 y</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: ORIF</li> <li>O: full recovery</li> </ul>
Gobbi et al <sup>10</sup> (2016)	41 and male	<ul style="list-style-type: none"> <li>Medial tibial plateau including the tunnel</li> <li>Semitendinosus</li> </ul>	<ul style="list-style-type: none"> <li>During soccer game</li> <li>Pain and swelling</li> <li>4.5 y</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: ORIF</li> <li>O: full recovery</li> </ul>
Wong and Muir <sup>44</sup> (2013)	25 and female	<ul style="list-style-type: none"> <li>Anteromedial corner of medial tibial plateau</li> <li>Hamstring</li> </ul>	<ul style="list-style-type: none"> <li>During rehab protocol of ACL</li> <li>Pain, swelling, inability to weight-bearing</li> <li>3 wk</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: no weight-bearing</li> <li>O: full recovery</li> </ul>
De Oliveira Carneiro et al <sup>46</sup> (2015)	17 and male	<ul style="list-style-type: none"> <li>Metaphyseal tibial fracture comprising ATT</li> <li>BPTB</li> </ul>	<ul style="list-style-type: none"> <li>Twist of the knee and fall</li> <li>Pain and inability to weight-bearing</li> <li>4 mon</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> </ul>	<ul style="list-style-type: none"> <li>T: ORIF</li> <li>O: full recovery</li> </ul>
Yoon et al <sup>48</sup> (2015)	21 and male	<ul style="list-style-type: none"> <li>Medial condylar fracture through the tibial tunnel</li> <li>Hamstring</li> </ul>	<ul style="list-style-type: none"> <li>During marathon</li> <li>Pain, swelling, hemarthrosis</li> <li>3.5 y</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: conservative with cast and brace</li> <li>O: full recovery</li> </ul>
Brown et al <sup>58</sup> (2016)	45 and male	<ul style="list-style-type: none"> <li>Fracture and avulsion of ATT</li> <li>BPTB</li> </ul>	<ul style="list-style-type: none"> <li>During rehab protocol of ACL</li> <li>Pain of anterior region and flexed knee, reduction of ROM</li> <li>2 wk</li> </ul>	<ul style="list-style-type: none"> <li>X-Rays</li> <li>CT</li> </ul>	<ul style="list-style-type: none"> <li>T: ORIF with screw</li> <li>O: full recovery</li> </ul>

Abbreviations: ACL, anterior cruciate ligament; ACL-R, ACL-reconstruction; ATT, anterior tibial tuberosity; BPTB, bone patellar tendon bone; CT, computerized tomography; MRI, magnetic resonance imaging; ORIF, open reduction and internal fixation; ROM, range of motion.



**Table 3** Summary of case reports describing tibial fracture after ACL-R

Authors	Age (y) and gender	Graft/procedure	Timing	Type of trauma and fracture	Treatment (T) and outcome (O)
Ternes et al <sup>70</sup> (1993)	19 and female	<ul style="list-style-type: none"> <li>Gore-tex graft</li> <li>ACL revision</li> </ul>	8 weeks	<ul style="list-style-type: none"> <li>Twist of the knee</li> <li>Supracondylar femur fracture into diaphyseal hole</li> </ul>	<ul style="list-style-type: none"> <li>T: remove of fixation system and ORIF with plate</li> <li>O: not reported</li> </ul>
Berg <sup>69</sup> (1994)	38 and female	<ul style="list-style-type: none"> <li>BPTB</li> </ul>	2 months	<ul style="list-style-type: none"> <li>Fall</li> <li>Displaced coronal fracture of posterior half of the lateral femoral condyle</li> </ul>	<ul style="list-style-type: none"> <li>T: multiple lag screws</li> <li>O: displaced of the fracture at 3 months. Iliac crest graft and re-fixation. Persistent non-union: ORIF with plate. Stable knee but reduction of ROM</li> </ul>
Wiener and Siliski <sup>68</sup> (1996)	38 and male	<ul style="list-style-type: none"> <li>BPTB</li> </ul>	7 months	<ul style="list-style-type: none"> <li>Dull tight pain during weight-bearing</li> <li>Oblique stress fracture at the junction of the distal shaft and metaphysis.</li> </ul>	<ul style="list-style-type: none"> <li>T: intramedullary femoral rod was inserted into the femur</li> <li>O: ROM 8–100°, No instability</li> </ul>
Manktelow et al <sup>61</sup> (1998)	26 and male	<ul style="list-style-type: none"> <li>Hamstring</li> </ul>	2 years	<ul style="list-style-type: none"> <li>Fall</li> <li>Lateral condylar fracture</li> </ul>	<ul style="list-style-type: none"> <li>T: Screws</li> <li>O: Full recovery</li> </ul>
Radler et al <sup>66</sup> (2000)	43 and female	<ul style="list-style-type: none"> <li>Over the top</li> <li>LAD-fixating cancellous screws for fixation</li> </ul>	25 months	<ul style="list-style-type: none"> <li>Fall</li> <li>Supracondylar and condylar femoral stress fracture (through the screw hole)</li> </ul>	<ul style="list-style-type: none"> <li>T: retrograde intramedullary nail</li> <li>O: mild instability and decrease ROM in flexion</li> </ul>
Wilson et al <sup>29</sup> (2004)	30 and male	<ul style="list-style-type: none"> <li>BPTB</li> </ul>	8 months	<ul style="list-style-type: none"> <li>Fall with pain, knee effusion, antalgic gait</li> <li>Displaced intra-articular fracture of the lateral condyle through the femoral tunnel</li> </ul>	<ul style="list-style-type: none"> <li>T: fixed with two screws</li> <li>O: full ROM, but not returned to sport</li> </ul>
Arriaza et al <sup>62</sup> (2006)	23 and male 20 and female	<ul style="list-style-type: none"> <li>Hamstring</li> <li>Absorbable screw for femoral fixation</li> <li>Hamstring</li> <li>Absorbable screw for femoral fixation</li> </ul>	6 months 4 months	<ul style="list-style-type: none"> <li>Pain in the medial side of the knee during jump and run</li> <li>Stress fracture of medial condyle</li> <li>Pain in the medial side of the knee during jump and run</li> <li>Stress fracture of medial condyle</li> </ul>	<ul style="list-style-type: none"> <li>T: conservative treatment</li> <li>O: full recovery</li> <li>T: conservative treatment</li> <li>O: full recovery</li> </ul>
Sheps et al <sup>67</sup> (2006)	22 and male	<ul style="list-style-type: none"> <li>Hamstring</li> </ul>	5 months	<ul style="list-style-type: none"> <li>No trauma.</li> <li>Supracondylar fracture through the femoral tunnel, with Endo-button displaced</li> </ul>	<ul style="list-style-type: none"> <li>T: open reduction and internal fixation with a 4.5 mm locking condylar plate</li> <li>O: full recovery</li> </ul>
Thangamani et al <sup>71</sup> (2009)	41 and female	<ul style="list-style-type: none"> <li>BPTB</li> </ul>	18 months	<ul style="list-style-type: none"> <li>Twist the knee, pain and unable to walk</li> </ul>	

Table 3 (Continued)

Authors	Age (y) and gender	Graft/procedure	Timing	Type of trauma and fracture	Treatment (T) and outcome (O)
Julien et al <sup>64</sup> (2010)	29 and male	<ul style="list-style-type: none"> <li>Hamstring</li> </ul>	–	<ul style="list-style-type: none"> <li>T-condylar distal femur fracture with spiral extension up the distal third of the femoral shaft</li> <li>Twist the knee with pain, effusion and limited ROM</li> <li>Fracture of lateral condyle of the femur through the tunnel</li> </ul>	<ul style="list-style-type: none"> <li>T: retrograde IM nail and percutaneous lag screw</li> <li>O: full recovery</li> <li>T: fixation with screws, cross-pin not removed</li> <li>O: not regained preinjury activity level</li> </ul>
Downen et al <sup>75</sup> (2013)	25 and male	<ul style="list-style-type: none"> <li>Hamstring</li> </ul>	7 years	<ul style="list-style-type: none"> <li>Patellar dislocation, incapacity to weight-bearing</li> <li>Pathological femoral fracture of lateral condyle</li> </ul>	<ul style="list-style-type: none"> <li>T: biopsy; giant cell tumor. Curettage of the tumor, high-speed burring, argon beam diathermy, removing the screw and insertion of polymethylmethacrylate bone cement.</li> <li>O: ROM 0–110degrees, return to low-impact sport.</li> </ul>
Keyhani et al <sup>74</sup> (2015)	35 and male	<ul style="list-style-type: none"> <li>Not note</li> <li>Revision procedure using the previous tunnel</li> </ul>	Intraoperative	<ul style="list-style-type: none"> <li>Over-reamed the previous femoral tunnel</li> <li>Coronal plane fracture of the lateral femoral condyle</li> </ul>	<ul style="list-style-type: none"> <li>T: two stages: ORIF with screws and graft the tunnel with cancellous bone</li> <li>Revision of ACL and remove the screws</li> <li>O: not note the recovery</li> </ul>
Heng et al <sup>76</sup> (2015)	35 and male	<ul style="list-style-type: none"> <li>Hamstring</li> <li>Double-bundle</li> </ul>	5 months	<ul style="list-style-type: none"> <li>Twist and fall</li> <li>Pain, unable of walking</li> <li>Distal femoral fracture with spiral extension proximally interesting the two femoral tunnels.</li> </ul>	<ul style="list-style-type: none"> <li>T: MIPO using plate</li> <li>O: full recovery</li> </ul>

Abbreviations: ACL, Anterior Cruciate Ligament; ATT, Anterior Tibial Tuberosity; BPTB, Bone Patellar Tendon Bone; CT, Computerized Tomography; IM, Intramedullary; MIPO, Minimal Invasive Plate Osteosynthesis; MRI, Magnetic Resonance Imaging; ORIF, Open Reduction and Internal Fixation; ROM, Range Of Motion.



ACL-R revision. The rate of infection after ACL-R reported in the literature ranges between 0.4 and 1.7%.<sup>11,14,15,77,78</sup> Many different microorganisms were isolated from synovial fluid of septic arthritis, such as *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, *Propionibacter acnes*, *Enterobacter*, *Enterococcus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella* and Methicillin-resistant *Staphylococcus aureus* (MRSA).<sup>77</sup>

Despite these bacteria are the most commonly involved in septic arthritis after ACL-R, there are few case reports describing uncommon pathogens related to ACL-R infection. Mei-Dan et al described an infection caused by *Staphylococcus lugdunensis* 4 days after an ACL-R performed with a BPTB graft,<sup>79</sup> while O'Neill reported a case of osteomyelitis due to a *Staphylococcus capitis* 4 years after an ACL-R performed with hamstring autograft.<sup>80</sup> Both pathogens were isolated from synovial fluid culture and the blood tests were suggestive for infection. The patient affected by *S. capitis* infection was treated with antibiotic therapy alone,<sup>80</sup> while the other patient underwent also an arthroscopic lavage.<sup>79</sup> Good outcomes with infection eradication were obtained in both the cases.<sup>79,80</sup>

Tubercular joint infection after ACL-R is considered a rare complication in Europe and the U.S.A. However, in an Indian hospital, Nag et al found that 0.69% (8 cases out of 26 septic arthritis) of infections after ACL-R were related to *Mycobacterium tuberculosis* (MTB).<sup>81</sup> Diagnostic criteria for septic arthritis due to MTB are: (1) positive stain for acid-fast bacilli (AFB) on joint samples, (2) a positive culture on Löwenstein-Jensen medium, (3) epithelioid granuloma with or without central caseation and Langhans-type giant cells at the histologic analysis, and (4) positive polymerase chain reaction (PCR) for *MPT64* gene of MTB.<sup>82</sup> Hamstring autograft was used in 7 patients and BPTB autograft in the last one. Four patients had a subacute onset, whereas other four had a late onset. All the patients complained about swelling, whereas warmth was present in 3 cases, low-grade fever in two and pain in the remaining two cases.<sup>81</sup> Furthermore, an isolated case of MTB infection was described by Oh et al in a 15 years-old girl who underwent ACL-R with autologous hamstring. She developed a wound dehiscence with yellow exudates and ROM reduction, 3 months after surgery.<sup>83</sup> In all these cases, blood tests and joint aspiration were performed. Increased erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were found in the eight cases from Nag et al,<sup>81</sup> while normal blood tests resulted in the case described by Oh et al.<sup>83</sup> However, in all the cases white blood cell (WBC) count was normal. In the cases described by Nag et al, joint fluid aspiration was turbid with an elevated WBC count but did not show any organism with Gram's stain. All patients underwent arthroscopic debridement and lavage: partial synovectomy was performed and tissue samples were collected and sent for cultures, including specific MTB tests. Cultures were positive for MTB in three patients. Histopathology showed the presence of typical epithelioid tissue in seven cases. AFB was seen in two biopsy specimens. DNA-PCR was performed in six cases and in all the cases it was positive for MTB. All the patients were treated for MTB with good out-

comes and complete recovery.<sup>81</sup> In the case described by Oh et al, the patient underwent three arthroscopic irrigation and debridement without any success. During the last arthroscopy the fixation screw was removed and sent for both pyogenic and MTB organism cultures. The test showed a massive growth of *Mycobacterium fortuitum*. Patient begun immediately appropriate pharmacological treatment with complete recovery.<sup>83</sup>

Fungal infection after ACL-R is a rare but devastating complication with severe bone loss mostly due to delayed diagnosis. Three case reports of fungal infection after ACL-R are described in literature. Mirzatolooei reported seven patients in which the fungal infection was probably related to a mistake during equipment sterilization and three cases were ACL-R infected by *Alternaria*.<sup>84</sup> Muscolo et al described six cases with mycotic infection after primary ACL-R, five cases were positive for *Rhizopus microsporus* and one case for *Candida albicans*.<sup>85</sup> Furthermore, Sun et al described a single case of *Aspergillus* infection after ACL-R.<sup>86</sup> In all these cases the symptoms begun 2 to 3 weeks after ACL-R and the clinical presentation were similar with fever, pain, and swelling. In all the cases blood tests as well as joint aspiration were performed. WBCs, ESR, and CRP were increased, the synovial fluid was turbid as in presence of an acute septic arthritis with increased WBCs count and polymorphonuclear neutrophils percentage. All the cultures were negative for bacterial. Systemic antibiotic was promptly begun in all the cases suspecting a low virulence bacterial infection. Serial X-rays and MRI showed cartilage destruction and destructive arthritis in all the cases.<sup>84-86</sup> Most of the patients did not respond to the antibiotic treatment. In the first patient, Mirzatolooei performed an arthroscopic irrigation and debridement, followed by an open approach to perform wide debridement and fixation device removal. The device was sent for cultures, including fungi, and it resulted positive for *Alternaria*; antifungal therapy was begun immediately, with infection eradication but ROM reduction. The second and the third patients had the same clinical presentation of the first one, with a faster diagnosis and treatment, resulting in better outcomes.<sup>84</sup> All the cases described by Muscolo et al underwent a surgical treatment, with a medial para-patellar approach, wide synovectomy, graft and implant removal, curettage, and massive bone resection due to severe bone necrosis involving the distal femur or the proximal tibia med. In some patient, a temporary cement spacer was used to maintain the joint space. In one patient an arthrodesis with intercalary allograft and intramedullary nail was required because of the massive bone losses and extensor apparatus damage.<sup>85</sup> In the cases described by Sun et al, an empirical antibiotic treatment was initially begun because the not-fungal specific cultures resulted negative. The patient underwent arthroscopic irrigation and debridement twice, and the last time a total synovectomy, as well as graft and implant removal was performed. Patients' symptoms did not resolve, so the authors performed an open debridement and tissue samples were sent to three different laboratories, with a positive result for *Aspergillus*. Antifungal therapy had begun immediately with infection eradication. However, due to the

massive bone disruption, the patients underwent one more surgery, with bone transport and arthrodesis with Ilizarov's.<sup>86</sup> In conclusion, fungal infections are rare but devastating complications after ACL-R. The massive bone loss due to late diagnosis often required radical treatment in young patient. ► **Table 4** summarized these case reports in detail.

### Rare Vascular Injuries

Vascular injuries associated with ACL-R are very rare and account for less than 1% of all the complications.<sup>87,88</sup> Injuries to the popliteal artery are more common during posterior cruciate ligament (PCL) reconstruction compared with ACL-R.<sup>89</sup> However, some minor vessels, such as the geniculate arteries, can also be injured during an ACL-R. There are three case reports in literature describing uncommon vessels injuries during ACL-R. Tsubosaka et al described a case of a pseudo-aneurysm of the articular branch of the descending genicular artery after a double-bundle ACL-R in an 18-year-old male. Two days after surgery, the patient presented with a pulsing mass on the medial side of the knee. Popliteal and dorsal artery pulses were normal. Due to the unusual presentation of the pulsatile mass, CT angiography was performed and showed a pseudo-aneurysm of the articular branch of the descending genicular artery. The pseudo-aneurysm was embolized and the patient completely recovered.<sup>90</sup> Lamo-Espinosa et al reported the case of a 27-year-old male who underwent a single-bundle ACL-R with a BPTB allograft. The day after surgery, the patient presented an active pulsatile bleeding and knee swelling. Arthrocentesis showed haemarthrosis and 60 cc of blood were extracted. Because of the bleeding, patient was referred to endovascular treatment, including an arteriography via the left common femoral artery. After contrast injection, the injury of the inferior lateral genicular (ILG) artery was localized and selectively embolized.<sup>91</sup> The authors attributed the ILG artery damage to the anterior horn partial meniscectomy of the lateral meniscus because it required passing the shaver close to the synovial capsule and to the ILG.<sup>91</sup>

Kim et al described case of a 31-year-old male who underwent arthroscopic anatomic single-bundle ACL-R. On the day 1 after surgery, the patient complained about pain around his left ankle without motor or sensory deficits. The pulses were palpable in the lower leg. Authors prescribed nonsteroidal anti-inflammatory drugs in the suspicion of an inflammatory process. The day after, the patient complained a small sensory deficit on the dorsal aspect of the foot, without any vascular deficit or pain increase at rest or during passive muscular stretching. After 2 days, the patient presented with a severe edema and pain exacerbation in the ipsilateral lower leg. An angiography was performed showing a thrombosis of both the left popliteal and anterior tibial arteries. The screw tip seemed to be close to the occlusion site in both the arteries. Postoperative X-rays showed that the position of the tibial tunnel was good but the screw was too long and its direction was too posterior. The diagnosis was a compartment syndrome due to direct drilling injury to the anterior tibial artery and a fasciotomy was immediately

performed for decompression. The pain was resolved but a debridement and excision of the necrotic extensor hallucis longus, extensor digitorum longus, and anterior tibialis muscles was required 9 days after ACL-R.<sup>92</sup>

### Nerve Injuries

During ACL-R, iatrogenic injuries to the infrapatellar braches of the saphenous nerve are not uncommon,<sup>93</sup> and some authors described a reduction in their incidence if an oblique skin incision instead a vertical incision is performed for hamstring graft harvesting.<sup>94</sup> Injuries to the saphenous nerve,<sup>95,96</sup> the sciatic nerve,<sup>97</sup> and the common peroneal nerve are less common in ACL-R surgeries.<sup>98,99</sup> Five case reports are described in literature reporting about rare nerve injuries in ACL-R.<sup>95-99</sup> One case report was excluded from the analysis because full data were not available.<sup>95</sup> In one case, a BPTB graft was used,<sup>99</sup> while in the other patients hamstring autografts were chosen.<sup>96-98</sup> In all the cases, the symptoms begun immediately with sensory deficit in the medial side of the leg in case of saphenous nerve damage,<sup>96</sup> in the lateral side of calf muscles and dorsal foot in association to loss of function if the common peroneal nerve was involved<sup>98,99</sup> or complete sensory and motor deficit of the leg if the sciatic nerve was involved.<sup>97</sup> In case of saphenous nerve damage, the diagnosis was done with the clinical evaluation.<sup>96</sup> When a neuropathy of the common peroneal or sciatic nerve was suspected, an MRI and electromyography were performed to evaluate the level and entity of the injury.<sup>97,98</sup> In the case described by Papoutsidakis et al of peroneal nerve damage, the injury was due to a too long tibial screw that was directed toward the fibular neck; this is the only case in which iatrogenic cause of the injury was described. The screw was removed and the patient recovered.<sup>99</sup> In the cases described by Vardi<sup>97</sup> and Balkey and Biant, the injury was probably related to the direction of the tendon stripper during hamstring harvesting.<sup>97,98</sup> Nerve revision was performed in three cases. In two cases, the damaged nerve was explored and debrided, one patient was fully recovered<sup>97</sup> and the other one complained about persisting sensory deficit.<sup>96</sup> In one case, peroneal nerve damage was repaired using a sural nerve graft but the patient still complained about loss of strength, loss of activity, and sensory deficit.<sup>98</sup>

### Other Rare Complications

Myositis ossificans (MO) is as a rare complication after knee surgeries. It is a benign process characterized by heterotopic ossification usually related to muscular trauma, such as contusion or strain.<sup>100</sup> MO etiology is still unclear and different theories have been proposed: transformation of intramuscular hematoma into bone, hematoma calcification, intramuscular bone formation from a detached periosteal flap, osteoblast proliferation from periosteal rupture, and metaplasia of intramuscular connective tissue cells.<sup>101</sup> Yamagami et al described a case of 27-year-old woman who underwent arthroscopic anatomical double-bundle

**Table 4** Summary of case reports describing rare infection after ACL-R

Authors	Pathogen and timing	Graft	Clinical presentation	Laboratory, analysis and diagnosis	Treatment (T) and outcome (O)
Mei-Dan et al <sup>79</sup> (2008)	<i>Staphylococcus lugdunensis</i> and 4 d	BPTB allograft (revision)	Fever, local warm, edema, and tenderness	<ul style="list-style-type: none"> <li>Blood: ERS, CRP, and WBCs</li> <li>Synovial fluid: 35,000 of WBCs</li> <li>Cultural of SF: +</li> </ul>	<ul style="list-style-type: none"> <li>T: antibiotic IV and arthroscopic lavage</li> <li>O: graft intact and full recovery</li> </ul>
Muscolet al <sup>85</sup> (2009)	<i>Rhizopus microsporus</i> in five cases, <i>Candida albicans</i> in one case, and median of 14 (10–17) d	BPTB in one case, hamstring in five cases	Pain and severe reduction of ROM	<ul style="list-style-type: none"> <li>X-rays, CT, and MRI: bone loss and necrosis</li> <li>Aerobic, anaerobic, mycobacterial, and fungal cultures were obtained from joint fluid, synovial lining, ACL graft and bone</li> <li>Histopathologic analysis: chronic inflammation, bone necrosis, and the presence of non-septate hyphae in all patients.</li> </ul>	<ul style="list-style-type: none"> <li>T: open debridement: synovectomy, removal of implants and graft, curettage, and massive bone resection resulting from severe bone necrosis. Cement spacer in all patient. Antibiotic therapy based on vancomycin and rifampicin immediately after surgery.</li> <li>O: In four cases massive resection of metaphyseal bone: three-fourth only one preserved articular surface allograft-prosthesis composite</li> <li>O: One-fourth massive bone loss and lesion extensor mechanism of knee, arthrodesis stabilized with intramedullary nail</li> <li>O: In two cases curettage and articular surface was preserved</li> </ul>
Nag et al <sup>81</sup> (2009) 8 cases	MTB, four subacute onsets (5–9 d), four late onsets (15–27 d)	BPTB in 1 case, hamstring in 7 cases	Swelling, fever in two cases, pain in two cases, warmth in three cases	<ul style="list-style-type: none"> <li>Blood: ERS, CRP, and WBCs normal</li> <li>SF: WBCs</li> <li>Culture of SF: increase in WBCs</li> <li>Culture of synovial tissue for MTB: + in three cases</li> <li>Histological exam of synovial tissue: epithelioid cells in seven cases</li> <li>DNA-PCR: + in six cases</li> </ul>	<ul style="list-style-type: none"> <li>T: arthroscopic debridement and lavage and Antitubercular therapy</li> <li>O: graft tension normal in all cases</li> </ul>
Oh et al <sup>83</sup> (2010)	<i>Mycobacterium fortuitum</i> and 3 mo	Hamstring autologous	Area of dehiscence distally with yellow exudate at the tibia	<ul style="list-style-type: none"> <li>Blood: WBCs, ERS, and CRP –</li> <li>Culture of intraoperative sample: – (not specific for MTB)</li> <li>Culture of fixation device (specific for MTB): +</li> </ul>	<ul style="list-style-type: none"> <li>T: empirical antibiotic therapy</li> <li>O: Three arthroscopies Antitubercular therapy</li> <li>O: full recovery</li> </ul>

Table 4 (Continued)

Authors	Pathogen and timing	Graft	Clinical presentation	Laboratory analysis and diagnosis	Treatment (T) and outcome (O)
Sun et al <sup>86</sup> (2012)	<i>Aspergillus</i> and 18 d	Hamstring autologous	Swelling, persistent fever	<ul style="list-style-type: none"> <li>Blood: WBCs, ERS, and CRP</li> <li>Culture of SF: –</li> <li>MRI: intra-articular effusion, edema of bone marrow around the femoral bone tunnel</li> <li>CT: bone destruction in the distal femur, circular bone defect, texture disorder of trabecular bone, and soft-tissue swelling</li> <li>Histological exam and cultural of tissue of synovia (during open debridement) sent to three laboratories: + for <i>Aspergillus</i></li> </ul>	<ul style="list-style-type: none"> <li>T: empirical antibiotic therapy</li> <li>Arthroscopy irrigation and debridement. Second arthroscopy with total synovectomy, removal of the graft and implants, and irrigation-suction drainage tubes into the bone tunnels and intra-articularly Serial open debridement</li> <li>Bone transport and arthrodesis with Ilizarov's</li> </ul>
Mirzatooei <sup>84</sup> (2014) 3 cases	<i>Alternaria (Pleosporaceae species)</i> and 2–3 wk	–	Fever, pain, and ROM reduction	<ul style="list-style-type: none"> <li>Blood: WBCs, ERS, and CRP normal</li> <li>SF: WBC with 90% of PMNs</li> <li>Cultural of SF: –</li> <li>X-ray: cartilage destroyed (in the first case)</li> <li>MRI: destructive arthritis (in the first case)</li> <li>Cultural of fixation device: +</li> </ul>	<ul style="list-style-type: none"> <li>T: serial arthroscopy joint, antibiotic IV, arthroscopy for remove fixation device. Antifungal IV.</li> <li>O: reduction of ROM in the first and second case, flexion contracture in first case. Full recovery in the others.</li> </ul>
O'Neill et al <sup>80</sup> (2013)	<i>Staphylococcus capitis</i> and 6 y	Hamstring autograft	Tender lump at the scar of graft harvesting and tibial tunnel placement	<ul style="list-style-type: none"> <li>Blood: WBCs, ERS, and CRP –</li> <li>X-rays: –</li> <li>MRI: enhancing soft tissue inflammatory mass with a central small pocket of fluid</li> <li>Cultural test on tissue from exploration of tibial tunnel: +</li> </ul>	<ul style="list-style-type: none"> <li>T: antibiotic IV</li> <li>O: full recovery</li> </ul>

Abbreviations: –, negative; +, positive; ACL, anterior cruciate ligament; ACL-R, ACL-reconstruction; B(P)TB, bone (patellar) tendon bone; CRP, C reactive protein; CT, computerized tomography; DNA, deoxyribonucleic acid; ESR, erythrocyte sedimentation rate; IV, intra venous; MRI, magnetic resonance imaging; MTB, *Mycobacterium tuberculosis*; PCR, polymerase chain reaction; PMNs, polymorphonuclear neutrophils; ROM, range of motion; SF, synovial fluid; WBCs, white blood cells.

ACL-R with hamstring using a three-dimensional (3D) fluoroscopy-based navigation system (StealthStation TRIA plus; Medtronic, Louisville, CO, U.S.A.) to create the femoral tunnel. Seven weeks after surgery the patient complained about the presence of a solid mass at the distal femur. X-rays and CT scans showed a heterotopic ossification localized at the drill hole performed for reference frame placement. An MRI showed a fluid effusion around the mass. Patient was substantially asymptomatic for pain and loss of function; the rehabilitation program was continued and the patient returned to daily activities without complications.<sup>102</sup>

Another rare complication after ACL-R is pigmented villonodular synovitis (PVNS) development. Rajani et al described the case of a 42-year-old woman with a previous ACL-R (16 years before), who began complaining pain and swelling in the same knee. The clinical examination revealed positive Lachman and anterior drawer test, with a palpable effusion. X-rays showed a radiolucent lesion suggestive for an aggressive process and MRI revealed diffuse PVNS extending along the ACL graft and causing bone loss within the tunnels. An arthroscopic biopsy of the synovium confirmed the diagnosis. The patient underwent a complete synovectomy, and the tibial and femoral bone defects were treated with cancellous bone chips.<sup>103</sup>

## Discussion

ACL-R is a very common orthopedic procedure<sup>1</sup> with good outcomes but a complication rate ranging from 1 to 15%.<sup>6</sup> Some relatively common complications are DVT, stiffness, complication related to graft harvesting, and common bacterial infection. However, there are different case reports in literature describing uncommon complications after ACL-R, such as rupture or migration of fixation device, tibial or femoral fractures, uncommon infections (unusual bacterial, mycobacterium, or fungal infection), rare vascular or nerve injuries, and other rare complications (MO and PVNS).

Despite fixation device, such as interference screws and cross-pins are commonly used in ACL-R, surgeons should know that a rupture or migration of the screw is possible, even months after the ACL-R. In these cases, patients may complain about pain, mechanical symptoms, or effusion. Tibial and femoral fractures are rarer compared with patellar fracture in ACL-R. However, they may occur for low energy trauma also months after the ACL-R due to the bone weakness related to the tunnel and a surgical treatment may be required. Different rare infections after ACL-R are described in literature with uncommon clinical presentation and difficult diagnosis. Fungal infections are often misdiagnosed because the patient is young and healthy but late diagnosis can cause dramatic joint disruption. Major vessels injuries are rare after ACL-R but different authors described injuries to minor vessels, such as geniculate arteries, presenting with pulsating masses and treated with selective embolism. Damages to the infrapatellar branch of the saphenous nerve are not uncommon after ACL-R. However, some authors also described few cases with saphenous, common peroneal or

sciatic nerve injury associated to ACL-R with potential severe consequences for the patients. Some authors also reported some cases of MO and PVNS after ACL-R.

In conclusion, ACL-R is a pretty common procedure, but surgeons should be aware about common but also rare complications and how to avoid, diagnose, and treat them.

### Conflict of Interest

R.R. is a teaching consultant for Zimmer Biomet and Smith and Nephew. All the other authors report no conflict of interest.

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