# Fractures around the knee region

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## Abbreviations

ACL - Anterior cruciate ligament

PCL - Posterior crciate ligament

PL - Patellar ligament

MCL - Medial collateral ligament

LCL - Lateral collateral ligament

CPM - Continuous passive motion machine

MRI - Magnetic resonance imaging

CT - Computed tomography

ORIF - Open reduction and internal fixation

LISS - The less invasive stabilization system

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## Summary

### Fractures around the knee region

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Fractures around the knee region comprise a numerous types and wide variation of injuries. The knee joint is a complex and one of the most important weight bearing joints in the human body, making him susceptible to different pathological states. It is formed by three different bones; distal femur, patella and proximal tibia. The stability and rigidity of the knee is made by balanced and intertvened connections of musculo-ligamentous system. The most important representatives of the ligamentous system are: anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), patellar ligament (PL), medial collateral ligament (MCL) and lateral collateral ligament(LCL). The main stabilizers of the musculoskeletal system are the extensors, flexors, adductors and abductors of the femur, whose distal tendons attach at various points on the knee joint, together with the tibial and fibular muscles and their proximal tendon attachments. However, this paper will be concentrated on the skeletal system of the knee region. The focus will be centered to classifications of fractures of each individual bone in the joint, their anatomical structure, epidemiology, etiology, clinical picture, and most importantly different ways of treatment approach. The fractures around the knee region occur in both high energy trauma, such as car accidents, and low energy traumas, such as falls, contact sports, etc. However, high energy trauma injuries comprise a majority of cases of these kind of fractures. Due to this, surgeon's option for treatment is mostly by surgical approach.Clinically, the patients present with pain in the affected limb, edema, deformity of the leg and inability to stand on their feet. Clinical picture can vary depending on the location of the fracture together with damage of the surrounding structures. This is especially important considering supracondylar and proximal tibial fractures where cruciate and collateral ligaments are susceptible to injury due to their connection and proximity withbones itself. The definitive diagnosis is made by radiological imaging, anterior, posterior and lateral views, respectively. In most cases, MRI and CT provide visualization of the soft tissue injuries in the extensive injuries of the knee region, helping the surgeon to plan the definitive treatment option. Surgical open reduction and internal fixation is nowadays concerned to be a superior option of treatment in respect to improved alignment, bony union and functional outcome concerning the knee range of motion.

**Keywords:** *distal femur, patella, proximal tibia, open reduction, internal fixation*

## Sažetak

### Frakture u regiji koljena

### Marko Perojević

Prijelomi oko regije koljena sadrže brojne vrste i široke varijacije ozljeda. Zglob koljena je složen i jedan od najvažnijih zglobova u podnošenju težine u ljudskom tijelu, što ga čini osjetljivim na različita patološka stanja. Tvore ga tri različite kosti; distalni femur, patella i proksimalna tibija. Stabilnost i krutost koljena postižu se uravnoteženim i isprepletenim vezama mišićno-ligamentnog sustava. Najvažniji predstavnici ligamentnog sustava su: prednji križni ligament (ACL), zadnji križni ligament (PCL), patelarni ligament (PL), medialni kolateralni ligament (MCL) i lateralni kolateralni ligament (LCL). Glavni stabilizatori mišićno-koštanog sustava su ekstenzori, fleksori, aduktori i abduktori femura, čije se distalne tetive pričvršćuju na različitim točkama na zglobu koljena, zajedno s tibialnim i fibularnim mišićima te njihovim proksimalnim dodacima tetiva. Ovaj će se rad koncentrirati na koštani sustav regije koljena. Fokus će biti usmjeren na klasifikacije prijeloma svake pojedine kosti u zglobu, njihovu anatomsku strukturu, epidemiologiju, etiologiju, kliničku sliku i najvažnije različite načine liječenja. Do prijeloma oko regije koljena dolazi kod visokoenergetskih trauma, poput automobilskih nesreća, i kod niskoenergetskih trauma, poput padova, kontaktnih sportova itd. Međutim, ozljede s visokom energetskom traumom čine većinu slučajeva takve frakture. Zbog toga su mogućnosti kirurga za liječenje uglavnom operativnim pristupom. Klinički su bolesnici prisutni s bolovima u zahvaćenom udu, edemom, deformitetom noge i nemogućnošću stajanja na noge. Klinička slika može varirati ovisno o mjestu prijeloma zajedno s oštećenjem okolnih struktura. To je posebno važno s obzirom na suprakondilarne i proksimalne prijelome tibije, gdje su oštećeni i kolateralni ligamenti osjetljivi na ozljede zbog povezanosti i blizine uz samu kost. Konačna dijagnoza postavlja se radiološkim snimanjima, pogledima sprijeda, straga i bočno. U većini slučajeva MRI i CT pružaju vizualizaciju ozljeda mekog tkiva kod opsežnih ozljeda regije koljena, pomažući kirurgu da planira definitivnu mogućnost liječenja. Kirurški otvorenaredukcija i unutarnja fiksacija danas se smatraju superiornom opcijom liječenja s obzirom na poboljšano usklađivanje kostiju i funkcionalni ishod u vezi s kretanjama koljena.

**Ključne riječi:** *distalni femur, patela, proksimalna tibija, otvorena redukcija, unutarnja fiksacija*

# 1. Introduction

Fractures around the knee account for about 6% of all trauma admissions. The knee joint is mainly surrounded by three structural bones that give the joint its strength and functionality; distal femur, patella and proximal tibia. In comparison to other joints in the body, due to larger number of bones forming the joint, there is a number of possible pathological outcomes and variations of injuries that can disable the normal function, rigidity and strength of the knee.They are broadly divided into three groups, namely supracondylar and condylar fractures of the femur, tibial plateau fractures and fractures of the patella.Most commonly the fractures around the knee region are a result of high energy traumas, motor vehicle accidents and sports injuries in young and adult population. On the other hand, there are also low energy traumas such as falls from high grounds most commonly seen in elderly population. Epidemiologically speaking, we can say that due to the skeletal complexity of the knee region, fractures around the knee area comprise around 25-35% of injuries of the lower body fractures. Early diagnosis and plan of treatment are crucial for preventing further complication, especially considering posttraumatic arthritis. With the development of instruments necessary for surgical treatments, open reduction and internal fixation has become a gold standard for management of these injuries.

In this review, we shall discuss the anatomy, epidemiology and etiology for a better understanding of the matter as well as clinical picture, diagnosis and treatment approaches available in today's medicine as well as postoperative care of the patients.

# 2. Anatomy

## 2.1.Femur

The thigh bone, or femur is the longest, strongest and heaviest tubular bone in the body. It transmits bodyweight from the hip bone to the tibia when a person is standing. The length of the bone is approximately a quarter of the person's height. The femur consists of a shaft with a neck and two ends, proximally and distally.Proximal end consists of the head, neck, and two trochanters (greater and lesser). The proximal femur is L-shaped so that the long axis of the head and neck projects superomedially at an angle to that of the obliquely oriented shaft, an angle of inclination, which is the greatest at birth and gradually decreases until the adult age (115 – 140 degrees, averaging 126 degrees).The shaft of a femur is slightly bowed (convex) anteriorly and most of the surface smoothly rounded as needed for the origin of the extensors of the knee. Posteriorly, a broad, rough line, a linea aspera, provides aponeurotic attachment for adductors of the thigh. Inferiorly, linea aspera divides into medial and lateral supracondylar lines, which lead to medial and lateral femoral condyles. The medial and lateral femoral condyles make up almost the entire distal end of the femur. Posteriorly and inferiorlytheir separation is made by intercondylar fossa and forming a longitudinal depression anteriorly, a patellar fossa, which articulates with patella.Lateral condyle has its central projection on the lateral surface, lateral epicondyle, and medial condyle its medial epicondyle to which superiorly adductor tubercle forms in relation to tendon attachment. The epicondyles itself provide proximal attachment for the medial and lateral collateral ligaments of the knee.

Distal femur

Since the area around the knee region comprises specifically distal femur, we shall discuss it furthermore.

The medial and lateral condyles differ both in shape and size. The lateral condyle is wider in front then at the back, while the medial condyle is of uniform width. Due to the oblique position of the shaft both condyles are in horizontal plane when person is in upright position despite their nonequal sizes. When we look at their position and curvature in transverse plane, both condyles are slightly and equally curved about the sagittal axis. In the sagittal axis condyles make up a curvature which increases posteriorly. This anatomical arrangement produces numerous transverse axes which permit the typical flexion of the knee joint that consists of sliding and rolling motion. At the same time it allows the collateral ligaments to

become sufficiently loose to permit rotation of the joint.Knowledge of physiological axes and their spatial relationship have animportant role in surgical planning of distal femur fractures.

### 2.2.Patella

The patella is a small bone located in front of the knee joint that protects the knee and connects the muscles in the front of the thigh to the tibia. The patella is the largest sesamoid bone of the locomotor system. The shape of the patella is triangular with its base facing proximally and its tip facing distally. The two surfaces, one faced towards the knee joint and other directed anteriorly, join at the lateral and a medial margin. The anterior surface is divided into three parts (upper, middle and lower third). The upper third consists of a harsh, flattened surface which serves for the attachment of the quadriceps muscle tendon. The middle third is comprised of numerous vascular canaliculi, while the lower third incloses the apex responsible for patellar ligament origin. When we talk about the inner surface, it is divided into articular surface and distal surface. The articular surface comprises three quarters of surface and the remaining distal part with vascular canaliculi is filled with adipose tissue, the infrapatellar adipose tissue, respectively. The articular surface area in the adult is around 12cm2 and is covered in the center by a cartilage of up to 6mm in thickness.

### 2.3.Proximal tibia

The tibia has a triangular shape with its proximal and distal ends. At the proximal end lie the medial and lateral condyles forming the superior articular surface interrupted by the intercondylar eminence that is further divided into a medial and lateral intercondylar tubercle. In front of and behind the eminence lie anterior and posterior intercondylar area. On the lateral condyle there is a small articular facet, directed laterally and distally for articulation with the fibula. The three sided shaft of the tibia has a sharp anterior border, which proximally becomes tibial tuberosity and becomes flattened distally. The fibula corresponds approximately in length to the tibia.

# 3. Epidemiology and etiology

## 3.1.Distal femur

Distal femur fractures account for less than 1% of all fractures and in between 3-4% of all femoral fractures with more than 85% of these injuries as low energy fractures in elderly (1,4). In other words, distal fractures of the femur are relatively uncommon. It seems that nature and etiology of these fractures show bimodal distribution (1). Most common cases are younger male patients, ranging from 20 to 35 years of age, and elderly women. The young adult population usually presents secondary to high-energy mechanisms, such as motor vehicle accidents, whereas elderly patients present typically after low-energy mechanisms, such as ground level-falls, and often present with significant co-morbidities. One study reported that 80% of patients 35 years of age or older with a distal femur fracture secondary to moderate trauma had evidence of generalized osteopenia (2). Among many others, professional athletes and military personel are typically found with distal femur fractures that are important to mention. These injuries usually result from high force trauma and could be possibly repeated afterwards.

## 3.2.Patella

Mechanism of injury in the patellar fractures are most often falling directly onto the knee by falling or slipping from stairs or receiving a sharp blow to the knee, such as dashboard hit to the knee in a head to head motor vehicle collision (3). The incidence of patellar fractures between 2005 and 2014 was 13.1/100,000/ year with a year-to-year variation with the distribution of incidence showing increase with the increased age (4). Male population predominantly experience these injuries in 10-19 age group, while female patients mostly average 70 years of age.

## 3.3.Proximal tibia (tibial plateu)

Tibial plateau fractures account for 1% of all fractures. They usually result out of high energy mechanisms, such high landing on feet, vehicle collisions, blow to the knee etc. The lateral part of the tibial plateau is more often affected, while medial part requires much larger force for fracture to occur (8). Due to these high energy forces, tibial plateau fractures are commonly bicondylar fractures rather than isolated medial or lateral plateau fractures.Young male population is more often susceptible the high energy traumas. The low energy mechanisms are also possible, however these type of injuries are seen in elderly patients with osteoporotic diseases and more commonly in women. In general, tibial plateau fractures because of its mechanism of injury is quiet often presented with associated vascular and soft

tissue injuries. Approximately 50% of knees with closed tibial plateau fractures have injuries of the menisci and cruciate ligaments that usually necessitate surgical repair. The incidence of proximal tibial fracture 10.3 per 100,000 people annually with the mean age averaging 52.6 years (5). As already mentioned, these fractures show bimodal presentation with men younger than 50 sustaining high energy traumas and women older than 50 years of age secondary due to falls. Overall, men are more commonly affected.

# 4. Classification

## 4.1.Distal femur (supracondylar fractures)

Comprehensive classification of supracondylar fractures of femur defines the fracture, indicates its prognosis and helps in making the best decision for type of internal fixation to use. ‘’The fractures are divided into type A, which are extra-articular, type B, which are partial articular fractures with part of the articular surface intact and in contact with the diaphysis, and type C, the complete articular fractures in which the articular surfaces are not only fractured but have also lost continuity with the diaphysis’’ (6). Each major type is subdivided into subtypes in ascending order of their complexity.

A1 – simple, extraarticular

A2 – metaphyseal wedge, extraarticular

A3 – metaphyseal complex, extraarticular

B1 – lateral condyle, saggital, partial articular

B2 – medial condyle, sagittal, partial articular

B3 – frontal, partial articular

C1 – simple (articular, metaphyseal) complete articular fracture

C2 – complex metaphyseal complete articular fracture

C3 – complete multifragmentary articular fracture

## 4.2.Proximal tibia (tibial plateau)

Tibial plateau fractures differ amongst themselves in their pattern of fracture, therapeutic approach and their prognosis. The most common method for classifying tibial plateau fractures is Schattzker’s classification, which groups fractures into six types. Each subsequent type of fracture is more serious from the previous one in terms of the amount of energy delivered to the bone at the time of injury. The classification is a very important tool for prognosis of injury and fracture itself, showing the same pattern, and with each subsequent type the prognosis is worse. On the other hand, each type groups fractures according to similar features, i.e. similar pathogenesis, and problems that occur during treatment as well as similar prognosis(6).

- Schatzker type I

  This type is characterized by a wedge-shaped fracture of the lateral part of the tibial plateau, initially defined as a fracture with a fragment depression of less than 4mm. Wedge fragment can be either separated from the metaphysis of the bone, or shifted downward, and is often simultaneously separated and shifted. This type is most commonly seen in young age population, mostly due to their bone density restricting any further fragment depression.

- Schatzker type II

  Type II is the most common of all tibial plateau fractures (25%). It is characterized also as wedge-shaped fracture of the lateral part of the plateau, but this time with depression
  of fragment larger than 4mm. It occurs with a higher frequency in people older than 40
  years due to osteopenia which favors greater depression of the bone fragment.

- Schatzker type III

  In this type, depression of the articular surface of the lateral plateau occurs without an associated one
  wedge fracture. Schatzker III is divided into two other subtypes: with lateral
  depression (Schatzker IIIa) and with central depression (Schatzker IIIb). More often, it affects a population between the ages of 55 and 60 and is the least serious of all fractures of the tibial
  plateau

- Schatzker type IV

  Type IV is characterized by a fracture of the medial plateau of the tibia, with a cleft or depression
  fragments. This type accounts for 10% of all fractures of the tibial plateau and is the worst
  forecasts. This form of fracture increases the likelihood of peroneal nerve injury, popliteal blood vessels, and medial collateral ligaments injury.

- Schatzker type V

Type V is a bicondylar fracture consisting of a wedge fracture of medial and lateral part of the tibial plateau, most often without fracture depression.

- Schatzker type VI

  A key feature of this type of fracture is a transverse subcondylar fracture with separation of the metaphysis from the diaphysis and further fracture of one or both condyles. This type of fracture is a consequence of high-energy trauma and accounts for 20% of all fractures of the tibial plateau. It is treated exclusively surgically.

### 4.3.Patella

Patella is a sesamoid bone that develops within the tendon of quadriceps muscle. In the classification of patellar fractures,there is always a concern whetherdisruption of extensor muscles mechanisms, the quadriceps muscle, has happened or not. Also, in many injuries, there is a question whether the operation is necessary or not. The decision to operate or not is based on the stability of the fracture. In other words, stable fracture do not require operation, while unstable fractures need to be operated. There are three groups of fractures of the patella(6).

- Osteochondral fractures

  Osteochondral type of fracture usually results from patellar dislocation. Most commonly it involves varying portions of medialfacet and subjacent bone. This fracture is often not seen in classical anteroposterior views and must be looked for on a skyline view of the patella. In this injury, the extensor mechanism is intact.
- Stellate fractures

  Stellate, or a vertical fracture, is most frequently a result of direct blow to the patella. The quadriceps muscle mechanism is undisturbed and the retinacula are not torn. The stability of the fracture is stable, patient is able to perform straight leg raising against gravity and not requiring surgery.
- Transverse fractures

  In most of the situations, transverse fractures rarely occur alone. These fractures are a result of violent contraction of quadriceps muscle, such as during attempt to stop the fall from stumbling. They can be displaced or undisplaced. In most of the cases there may be avulsion of quadriceps tendon, or of the infrapatellar tendon with the possible tear of the reticular expansion. Extensor mechanism is nondisrupted and the fracture

is considered stable if the fracture undisplaced.However the fracture is potentially hazardous. If the strong and sudden contractions of the quadriceps occur further more, retinacular expansions might tear, the fracture will displace and extensor mechanism will be disrupted.

- Multifragmentary fractures

  Multifragmentary displaced fractures are usually result of a high-energy force and are frequently associated with the fractures of femur. Victims of vehicle accidents are one of the most common representatives of these kinds of injuries. A combination of forces, such as straight blow to the patella combined with displacing forces, rip patella apart. Due to these compressive forces, the separate fragments of the articulation are found displaced and possibly impacted into the underlying bone. It is crucial to recognize these small fragments in addition to major ones, otherwise the incongruent articular surface is a predisposition to posttraumatic arthritis. The reticular expansions are torn and the patient is unable to perform full extension of the knee against the gravity.

# 5. Clinical manifestations

## 5.1.General

The anamnestic data are highly important in determining the cause, time, place and mechanism of the injury. This information is especially useful in cases of emergency unconcious trauma patient where heteroanamnesis has a crucial role in defining a working diagnosis. If there is an emergency conscious trauma patient, subjective answers of the patient during anamnesis can have large impact on making a differential diagnosis as soon as possible.

After anamnesis the physical examination is being done with inspection and palpation to check for specific and unspecific signs of fracture. With the physical exam we can easily determine whether the fracture is opened or closed one. The next step is defining if there is any vascular or associated nerve injury together with estimation of isolated or part of multiple injuries. Also the inspection of any rotations, angulations and shortenings of the limb represent a specific signs of fracture itself. Neurovascular status is checked with palpation and inspection to define if any injury occurred by fragments that can damage vessels and nerves of the affected area.

## 5.2.Distal/supracondylar fracture

Most patients with distal femur fractures are unable to put any weight on the injured leg. They experience pain in the knee and sometimes radiating to the thigh. General symptoms are mostly tenderness to touch, swelling, bruising and possible deformity usually presented as shortening of the fracture with varus and extension of the distal articular segment. This deformity is the most typical one and is due to varus and extensor mechanismunable to oppose the pull forces of hip adductors and gastrocnemius muscle (7).

## 5.3.Patellar fracture

History of patients with patellar fractures usually shows pain in the anterior knee caused by fall or dashboard injury, and not so uncommonly with sudden flexion of the knee with contracted extensor muscles.

Physical exam by inspection shows palpable patellar defect and possible hemarthrosis. Motion of the knee is restricted especially when extensor mechanism is damaged together with retinacular disruption. In that case, patient is unable to perform straight leg raise. However, if the patient is unable to move the knee at all due to the pain, there is a possibility of hemarthrosis aspiration and injection of local anesthetic (3).

### 5.4.Tibial plateau fractures

Full clinical assessment of tibial fractures is necessary with palpation and inspection. It must be noted that in most tibial plateau fracture there is associated soft tissue injury, most commonly the collateral ligaments of the knee with mensci tear, and clinical tests for these anatomixal structures are obligatory. Physical examination begins with circumferential look to rule out open fracture and with palpation it is important to see if compartment syndrome is present when compartments are firm and not compressible. If any differences in the pulse exam are found, the neurovascular injury should be suspected and further investigated with ankle brachial index measurement. Symptoms present as pain and inability to stand on the affected leg, together with possible contusions, hematomas, discolorations of sin, etc. One of the specific signs of tibial plateau fracture can be effusion of the knee leading us to most likely to associated soft tissue injury.

# 6. Radiological imaging and diagnosis

## 6.1.Distal femur

Radiological examination is a necessity in making the diagnosis of the specific fracture and obtaining a detailed view of the fracture. The x-ray images are taken in anteroposterior, lateral, and two oblique views of the injured site. Alsothe uninjured side is obtained with anteroposterior and lateral roentgenograms as the template, needed for pre-operative graphic planning of the surgical reconstruction. However, roentgenograms have been basically replaced by the development of CT scans. If we talk about complex intraarticular fracture, frontal and sagittal CT reconstructions have shown to have crucial part of the routine evaluation of the fracture. They allow us to gain a detailed picture of the intraarticular components, specific orientation of the fracture lines, and enabling to form a 3D concept of fracture. Considering the MRI imaging, it has been considered not to play as major role as the CT scan. However, if there is a suspicion of associated soft tissue injury, such as ligamentous disruptions, MRI is found to be very useful.

## 6.2.Tibial plateau

Recommended radiological images are anteroposterior, lateral and oblique view, which is specifically helpful in determining the amount of depression that occurred from injury. The anteroposterior image gives us detailed view of the articular surface, joint alignment and possible sclerotic band of bone as indication of compression fracture. The lateral one allows us to find posteromedial fracture lines that must be recognized.

The articular depression and comminution are the most important anatomical dearrangements in tibial plateau injuries and furthermore detailed in view with CT-scan imaging. The MRI, due to high possibility of ligamentous disruption, is always considered when there is suspicion of soft tissue injuries. Otherwise, its use with these type of injuries is discussible.

## 6.3.Patellar fractures

Anteroposterior, lateral and skyline radiological views offer us a basis for evaluation and classification of the patellar injury. However, the CT scan imaging provides us even better information, especially considering lower pole fractures of the patella. Actually, it has been shown that the addition of the CT imaging to the radiological images resulted in the changes in the management plan of almost half of the cases (8). The use of the MRI has its usual role in detection of soft tissue injuries, together with detailed observation of the

cartilaginous components and subchondral fractures. This is particularly important due to possible extensor mechanism disruption that can happen with patellar injuries.

# 7. Treatment

## 7.1.Distal femur fractures

Supracondylar fracture of the femur has been considered, for a long period in the history, as unsolved problem in traumatology. Furthermore, patients would most often show varying degrees of permanent disability after treatment. Closed procedures, consisting of splinting and traction, were primary choice in the treatment. However, an inability to control the displaced articular fragments that weren't reduced with traction was a major issue, together with common complication of displacement of the fragments posteriorly. Another difficulty was a time frame of 6-8 weeks of bed resting supine position which consequently generated knee stiffness afterwards. On the other hand, open reduction and internal fixation were used occasionally, but with poor results. The reason was limited techniques of internal fixation and implants, with the main issue of maintaining the achieved reduction. The techniques and devices available at the time did not allow stable fixation making the early motion impossible. In the 1970, the first review of 112 patients with the supracondylar fracturesthat were treated according to anatomical reduction, stable internal fixation and early motion was published by AO group (6). The review showed 73.5% of patients with good or excellent results. With the advancement of techniques, it is considered nowadays that nonoperative treatment has been substituted with the techniques of stable internal fixation. Many reports have shown that conservative treatment in these fractureshave more than half of the cases with unsatisfactory results and lesser chances of bringing back the functional status to its normal level. However, the surgeon must take under consideration all aspects of the injury and the patient. This includes severity of the trauma, whether it is caused by high or low energy impact, fracture pattern, type and possible associated injuries. It is also important not to overlook patient's age, level of activity and functional demand which are required in the decision of whether to operate or not. The goal of clinical management is anatomical reduction, restoration of limb length, rotation and alignment. The alignment in both coronal and sagittal planes are important, with coronal plane showing even more significance regarding overall outcome. It has been shown that patients with healed fractures with more than 15 degrees of valgus or any degree of varus will develop posttraumatic arthritis at some point.

### Conservative treatment

Non-surgical approach to these fractures are mainly reserved for non-ambulatory patients and patients unable to tolerate surgical procedure, such as older patients with low bone

density incapable of proper healing after surgery. Absolute indications are nondisplaced and stable fractures with good alignment as well as patients with medical conditions who preclude surgical treatment. It should be noted that these indications are rare and most commonly surgical approach is the treatment of choice. Skeletal traction with casting and bracing are the two options in the conservative management of the patients with distal femur fractures. Traction is a mechanical system of weights and counter-weights that holds the broken pieces of bone together with a pin placed in a bone to position the leg. Casts and braces hold the bones in place while they heal. However, there is inability for early motion of the knee which increases the possibility of the knee stiffness afterwards together with higher chances of thromboembolic disease, brace wounds, ulcers and even formation of decubitus due to prolonged bed rest and inability to move.

**Surgical treatment**

Unless there is a case of open fracture, most distal femur fracture operations are delayed for 1 to 3 days in order to give surgeon a time for planning the operation and preparing the patient for the procedure. It is crucial to check for patient's medical history to exclude any medical issues that need to be addressed before the surgery. On the other hand, open fractures are susceptible to environment, giving no other option to surgeon but to immediately operate.Options for the surgical treatment of supracondylar femoral fractures include plates, intramedullary nails, external fixators, and total knee arthroplasty. The technique used is determined by fracture pattern, bone quality, the hemodynamic stability of the patient, and the skill and experience of the surgeon.

If we are dealing with patient who has damaged soft tissues around the fracture site or the patient is unable to tolerate longer procedures due to medical problems, we can apply the temporary external fixator. This device is a stabilizing frame that holds the bones in proper position until the patient is ready to undergo a surgery. Metal screws or pins are placed in the middle of the femur and tibia, which are attached to the bar outside of the skin. Thankfully, this allows stabilization before the surgery and gives time to evaluate proper surgical approach. When we talk about superior surgical approach, the advancement of internal fixation techniques allows more efficient management of these fractures and patients outcome overall. Generally speaking, ORIF is used for open fractures, displaced fractures, fractures associated with neurovascular compromise, irreducible fractures and pathologic fractures. The two most common methods of internal fixation are

intramedullary nailing, a specially designed metal rod inserted into the marrow canal of femur keeping it in position, and plates and screws. The development of internal fixation devices has brought many options to surgeon in terms of which technique to use for each individual patient. The 95° angle plate, condylar screw systems, condylar buttress plate, the less invasive stabilization system (LISS) and bridge plating are one of the main techniques used in internal fixation procedure. The condylar screw systems together with LISS have substituded the use of a 95° angle blade due to easier handling, sagittal plane adjustments that can be made in the plate position and their use for fractures with an intercondylar split.The condylar screw system is contraindicated when there is a low transcondylar fracture, a coronal fracture, or significant intraarticular comminution. However, 95° angle blade insertion does not necessitate removal of a large amount of bone. Therefore, very distal supracondylar fractures that extend to within 2 cm of the joint surface can be fixed with this device. Condylar buttress plate is a broad plate with a distal portion that is contoured to fit the lateral aspect of the distal femur. It may be used for the fixation of minimally displaced fractures, but is most useful in fractures with articular extension in the sagittal and coronal planes. It can also be used as an intraoperative backup device when difficulties are encountered with the angled blade plate or condylar screw system. The less invasive stabilization system (LISS) uses a locking plate and screw construct, which preserves the periosteal blood supply to the fracture. It is used in a similar technique as the buttress plate. The LISS plate is more often used in cases of patients with osteoporotic bone.The bridge plating technique is an indirect reduction technique that is appropriate for fractures with a long comminuted metaphyseal segment, an intact soft-tissue envelope, and an extra-articular fracture. The goal with a bridge plate is to span the fracture fragments to maintain the soft-tissue envelope with the choice of implant determined by the surgeon after which the plate is applied to the distal femur. The bridge plating technique is not appropriate if the soft-tissue envelope is not intact (as in severe open fractures), if marked osteoporosis is present, or if there is significant medial bone loss. Under such circumstances, supplemental fixation of the metaphyseal segment is necessary, and a bone graft should be applied to the medial defect. Finally, the total knee arthroplasty represents the treatment reserved for elderly patients with severe osteopenia or pre-existing arthrosis that unables normal healing and restoration of functionability. For these patients, this represents the most rapid return of function with immediate weightbearing after surgery.

### 7.2.Tibial plateau fractures

Conservative treatment

Indications for the non operative treatment are nondisplaced stable split fractures, fractures with minimal depression, submeniscal rim fractures, fractures with elderly, low demand people and osteoporotic patients. Functional cast bracing has been accepted as a first choice of treatment where the limb is allowed to do the restricted function with the brace in. With the intermittent loading of the fractured area and gradual weight bearing, vasculature and blood flow are promoted and helping in the process of healing. Before the functional cast bracing, long leg cast and traction mobilisation were used for some fractures.

Surgical treatment

Fractures of the tibial plateau in principle are almost always treated surgically, but the decision on how to treat a specific fracture depends on the morphological characteristics of the fracture, the degree soft tissue damage and the general condition of the patient. Common indications for surgery treatment of this type of fracture are: displacement of fragments greater than 2mm, angulation greater than 10°, open fracture, associated compartment syndrome and ligament injury, and ipsilateral fracture of the tibia or fibula (9). The procedure performed is osteosynthesis, i.e. bone fusion fragments using implants in the form of screws, nails or tiles, and allows the establishment of the anatomical bone relationships and rapid recovery of function. There are several anatomical approaches to proximal tibia: anterolateral, posteromedial, and minimal approach invasive osteosynthesis (10). There are two basic types of osteosynthesis used in modern fracture traumatology of this type: internal fixation, which is the basic principle to convert train forces, compression, bending and shear forces into axial compressive forces at the fracture site, and external fixation. In theinternal fixation, plates and screws are used, and in the case of intramedullary osteosynthesis, nails. Plate osteosynthesis has been shown to be beneficial in partial articular and intraarticular fractures, while osteosynthetic screws are applied in unstable, simple articular and partial articular fractures. Intramedullary osteosynthesis is often used in extraarticular fractures of the tibial plateau, and the advantage over the plate is when Küntscher nail fixation connects fracture fragments much more compactly (11). In addition to internal fixation, external fixation is also used, with a metal Schanz screw placed in the proximal and distal fragment over the outer metal frame that fixes fracture.

The external fixation has been shown to be particularly useful in fractures of the proximal tibia associated with extensive soft tissue damage and in polytraumatized patients (12).

### 7.3.Patellar fractures

Conservative treatment

Non operative approach to these fractures gives the physician a possibility to treat the patient with the knee immobilized in extension with brace or cylinder cast. In some cases it is even possible, with the cast or brace, for a patient to be able to bear a full weight on the injured leg. However, it is important,if the patient has a damaged extensor mechanism (unable to perform full leg raise), displaced fragments or vertical pattern of injury, operation is the only choice of treatment possible.

Surgical treatment

When we talk about displaced fractures, surgery is most likely the treatment of choice. In precise, open fractures with articular displacement of more than 2mm, displaced patella fracture of more than 3mm are indications for surgical treatment, together with failure of the extensor mechanism and sleeve patellar injuries in children (6). Internal reduction with internal fixation is the method of treatment to these injuries. Other methods that can be applied are partial patellectomy, for comminuted superior or inferior pole fractures measuring less than 50% patella height, and total patellectomy reserved for severe and extensive comminution unable to salvage.

# 8. Complications

## 8.1.Distal femur

Malunion, nonunion, loss of reduction of fracture, infection, wound complications in patients with diabetes, and deep vein thrombosis are all complications of supracondylar femur fractures. The most common errors, however, are considered to be caused by technical nature and therefore preventable. The most often complication is the incomplete reduction of joints resulting in incongruency of the joint surfaces and subsequently development of posttraumatic osteoarthritis. The second most common problem is failure to achieve interfragmental compression with lag screws and to apply axial compression to increase the stability of fixation. Ultimately, these errors will lead to angular deformations and malunions. Lastly, the surgeon must choose the proper selection and insertion of the condylar plate. Penetration of the medial cortex, irritation of the joint and synovitis can all occur if the blades are too long. Also there is a possibility of blade lying deep in the medial collateral ligament causing pain and knee stiffness.

## 8.2.Tibial plateau

Complications of the proximal tibia can be divided in early and late complications. Early complications are viewed as biological failures such as neurovascular injuries, compartment syndrome, infections, deep vein thrombosis, etc.. On the other hand, late complications are considered more as a mechanical problem. The examples are malunion of the fragments and their misalignment, knee stiffness and instability, late collapse and chronical development of osteoarthrosis. Acute compartment syndrome is the most common significant complication associated with fracture tibial plateau. It is characterized by a set of symptoms and signs that result in inadequate perfusion of one or more muscle sections of the lower limb, caused by compression of blood vessels and blood or edema after limb injury. Important functional complication of a tibial plateau fracture is the inability to restore normal walk. According to one case-control study, walking rhythm and stride length were reduced in patients with this type of injury, and walking speed was less than 18% compared to control group (13). Other complications include chronic pain area of fracture and surgical incision, as well as thinning and skin irritation above the site fracture (16).

### 8.3.Patella

It is reported that 2-10% of patients experience infection after patellar management (6). This is mostly because of the subcutaneous location of the patella and its lack of overlying soft tissue causing difficulties with healing of the tissue. With deep infections, surgical debridement and prolonged antibiotic therapy are mandatory. Otherwise, untreated infection can lead to septic arthritis with poor prognosis. Another common complication is stiffness of the knee due to prolonged inactivity. It is therefore very important to initiate the physical therapy as soon as soft tissue injuries are healed. There is also a relatively high percentage of patients, around 20% (6), that experience loss of fixation and reduction treated with internal fixation most often due to inappropriate fixation, unrecognized comminution or aggressive postoperative therapy.

## 9. Postoperative care

### 9.1.Distal femur

Splinting the joint by a surgeon is a necessary last step of the surgical procedure. The final outcome of the patients injury depends on preventing contractures that would result in loss of function and movement. Previously, the knee was splinted in the extended position. However, the AO group recommended immobilization of the knee in 90° flexion for 3-4 days following surgery (6). The most important advantage of this position is the rapid return of flexion. This range was previously often lost and caused permanent disability. After the splint is removed, patients are asked to begin active extension and flexion movements to regain the range of movements. It is important that the stability of the fixation and the bone quality of the patient is satisfactory. If the bone quality is good but not sufficient to allow early weightbearing, the patient may be allowedfor early motion but kept off full weightbearing until radiographs show bone healing approximately around 12 weeks. If the bone quality is low, more splinting may be required for about 6 weeks and then switched to a hinged brace with a postoperative physical therapy almost always required. On the other hand, not all patients are able to begin with nonprotective active exercise. Patients with soft tissue injuries, such as collateral ligament rupture, after initial splintingor rest are put in a cast brace with polycentric hinges without blocks. This allows early motion of the knee with protection from undesirable valgus or varus forces that can lead eventually to angular deformities of the extremity. If we are talking about the patient with associated ruptured cruciate ligament, the surgeon focuses on whether there has been avulsion of the piece of bone with the rupture (6). As discussed earlier, the main goal after open reduction

and internal fixation is motion. If there is avulsed bone, the surgeon securely fixes it with tension band wire or a leg screw. However, in the case of avulsion or a tear without a bone, the injury is ignored treated later due to necessity of early motion as ensurance for regaining range of movement. For severe fractures, complex and difficult fractures with damaged soft tissue envelope likely to result in stifness, advancement of continuous passive motion machines (CPM) have become an extremely important part of postoperative care in goal of regaining range of motion in such complicated patients.

### 9.2.Patella

The knee is immobilized in 40°-60° flexion and the leg elevated on a Bohler-Braun splint. Patient is kept in the position for 2 to 3 days after which surgeon assesses the wound and decides whether healing is satisfactory or not. If the wound healing is satisfactory, the patient is instructed to begin active extension and flexion exercises. With only partial weightbearing the patient continues to perform exercises for six weeks. The biggest mistake would be to immobilize patient in the cylindric cast.In the articular patellar fracture,after open reduction and internal fixation, the knee flexion is crucial in producing stabilizing effect of dynamic screw. Also, motion itself enhances healing of the cartilage and recovery in general. After six weeks of, patient is instructed to start with full weightbearing. In some cases, it is advisable to put on some kind of protection until quadriceps muscle gains its full strength together with tendons and ligaments (6).

### 9.3.Tibial plateau

If the open reduction with internal fixation has shown its stability and proper alignment, the padded dressing is applied to the knee in 45°-60° flexion on Bohler-Braun splint with the elevation of an extremity. During the first 24-48h, suction draining is applied to control postoperative swelling. After 2-3 days, patient is advised to start active motion of the knee if the wound is healing properly and without any complications (14). Usually, after 1 week patient has regained full extension and 90° flexion of the knee with the full flexion regained after 2 weeks. On the other hand, all major intra-articular and complicated, complex fractures should be treated with CPM immediately after surgery. Regardless of stability of fixation, weight bearing is not allowed for 10-12 weeks. Early active motion is an absolute necessity, but weight bearing can lead to loss of reduction, malalignment, incongruity and more importantly affect the healing process of articular cartilage immature of bearing load.

# 10. Conclusion

Fractures around the knee region comprise a wide variety of different types of injuries. Knee is formed by three main structural bones on which basis we divide these fractures in supracondylar, patellar, and tibial plateau fractures. Throughout the history till today, management of these fractures have always been challenging for the surgeons due to severity of the injuries, their location and possible complications that can accompany them. Causes can be due to high force traumas, most often in young male population in vehicle accidents, or low force traumas, most commonly in elderly people from falls. Most common symptoms are pain, edema, and inability to stand on the affected leg. In high force trauma, patients usually present with open fractures susceptible to complications. The diagnosis is confirmed by rentgenogram together with CT scanning and MRI for assessment of soft tissue injuries and more detailed view in general. Conservative treatment is reserved for simple, closed and nondisplaced fractures with immobilization, traction and manual reposition.

With the advancement of surgical devices and techniques, internal reduction and open fixation has become gold standard in the management of fractures around the knee region. Major problems such as knee stiffness, control of the displaced fragments, stability of the fixation and many others have been solved resulting in better outcomes in both functionality and movement of the patients. Detailed and individualised planning is nowadays crucial for successful treatment and the overall outcome for the patient. We can say in the end, that the future of surgical treatment and treatment of fractures in general have a bright future. Internal fixation and open reduction has opened many options to assess and treat the patient in the most optimal way with results showing positive rise in satisfactory treated injuries. However, surgeon’s knowledge, experience and planning is the standard basis for ultimate results and further advancements in the future of surgical techniques and approaches.

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# 13. Biography

Born and raised in Zagreb, Croatia. Attended the elementary school Ivan Goran Kovačić in Zagreb, after which I continued my high school education at 5. Gymnasium in Zagreb. At the University of Medicine I am a member of Student Society for Orthopaedics and Traumatology and an active member of School of Medicine Futsal association. Other activities include associative work with Prof. dr.sc. Sandra Marinović in making a paper for publication under name of "Compression and physiotherapy as treatment options for chronic vein insufficiency" and participated in translation of scientific paper "Late complications of long term intravenous cathethers use".

I was active hockey player for 16 years until my second year of medical studies. I have won multiple Croatian hockey championships in different age categories, received an award for the best goalkeeper of the season, and had the honour of being part of the National Croatian Hockey Team U-18. In my free time I play guitar and also as a rafting skipper during the summer on the Cetina river.