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THE TIBIAL PLATEU FRACTURES:
DIAGNOSIS AND TREATMENT

Editor:
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The Tibial Plateu Fractures: Diagnosis and Treatment

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DEDICATION

Dedicated to whom we love and to those who love us.

PREFACE

The importance of this argument arises from high incidence of tibial plateu fractures, from epidemiology of this kind of fracture (usually young and active people) and from necessity to obtain a good restoration of function.

Tibial plateu fractures are mostly articular fractures. The goal of treatment is restoration of function and fracture fixation must offer enough stability to allow early mobilisation.

Several problems are correlated to this kind of fracture:

- cutaneous and soft tissue damage are often present, as these fractures often result from high energy trauma
- diagnosis is sometimes difficult: x-ray, CT scans and MRI can be used without a correct standardization
- associated lesions of menisci or ligaments can influence the final outcome
- different procedures are described for tibial plateau fractures: conservative treatment, open reduction and internal fixation, with arthroscopic techniques, with external fixation, using “balloon” indirect reduction, *etc*.
- postoperative care is fundamental to obtain a good result, but the timing is not so clear

We think a book clarifying and summarizing anatomy, pathogenesis, diagnosis, treatment and rehabilitation can help all orthopaedics surgeons treating this disabling kind of fracture. Our objective is not to give a definitive answer about treatment choice, but to propose some solutions on the basis of the fracture “personality”.

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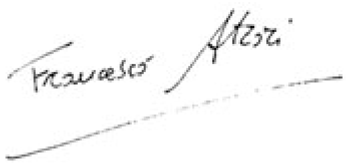

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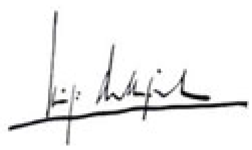

FOREWORD

It is a great pleasure to write the foreword for *"The tibial plateu fractures: diagnosis and treatment"*, edited by my colleagues and friends Francesco Atzori and Luigi Sabatini.

Techniques in traumatic knee surgery have continued to evolve and the editors of this book have described various possible surgical procedures. The authors articulate with clarity the best evidence available to support the use of the procedure they described as well as any controversial aspects of the technique and alternative treatment options if available.

Furthermore, every perspective of tibial plateau fractures is well represented, from epidemiology to rehabilitation protocols.

I think this e-book will be extremely precious for every orthopaedic surgeon, residents and fellows to manage tibial plateau fractures and I congratulate the Editors and the Authors on the production of a very interesting e-book.

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CHAPTER 1

Pathogenesis and Epidemiology of Tibial Plateau Fractures

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Abstract: Fracture of the tibial plateau is seen frequently in orthopedic trauma units and pose major threats to the structure and function of the knee joint. Tibial plateau fractures are complex injuries to treat due to their articular involvement and associated disruption of ligamentous structures in the knee. For many years several discussion has been done about the best treatment of tibial plateau fractures . A lot of orthopeadic surgeons and researchers have analyzed functional and radiologic results for nonoperative and surgical, treatments [1, 2]. Nevertheless the surgical treatment is mandatory in the tibial platueau fracture associated with an acute compartment syndrome or an acute vascular lesion and in open tibial plateau fracture.

Keywords: Articular fracture, Compartment syndrome, Epidemiology, Mechanism injury, Plateau fracture.

INTRODUCTION

- Tibial plateau is formed by medial and lateral tibial plateaus. They are the articular surfaces of the medial and lateral tibial condyles and they articulate with the medial and lateral femoral condyles, respectively. They are an essential part of knee joint, a diarthrodial joints, which provide a smooth, stable capacity

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Francesco Atzori and Luigi Sabatini (Eds)

for motion of the appendicular skeleton to perform specialized tasks [3].

- So it is essential to know the general bases for an effective treatment of any articular fracture:

The alteration of the articular surface joint often affect stability, cause pain, and disrupt effective range of motion of the joint. The inflammatory response combined with this type of fracture can create a massive fibrosis within the injured joint, exacerbated by inadequate immobilization or inappropriate surgical treatmentss. The malconsolidation of the fracture was often associated with a bony deformity, stiffness, pain, and functional disability. The anatomical restoration of the articular surface and freedom of joint movement is necessary to obtaine a favorable outcome [3].

EPIDEMIOLOGY

Epidemiology of Tibial Plateau Fracture

The prevalence of tibial plateau fractures is 1.3% of all fractures, males are more often affected than females. Several studies show that 71% of injuries occurred in those aged 30-60 years.

It isn't the most common tibial fracture, having a frequency of less than 10% [4, 5].

Both high energy trauma (*e.g.* motor vehicle, cycling and winter sports) and low energy trauma (*e.g.* falls, contact sports, distance running, and other endurance or repetitive impact activities) are commone causes of this kind of fracture.

It occurs principally in two groups of patient:

Younger or middle-aged patients, suffered of moderate or high-energy injuries (especially motor vehicle accidents or a fall from a height) and elderly osteoporotic patients, who suffered of low energy injury like a simple fall [5, 6].

When tibial plateau fractures are cause by falls from height, they can be associated with calcaneal fractures and fractures of the thoraco-lumbar spine, nevertheless in the majority of cases the lesion is isolated. It affect rarely the children and young adults prior to epiphyseal plate closure.

The principal causes are:

- Road traffic accidents 52%;
- Falls 17%;
- Sporting or recreational activities in 5% [5, 7].

There is a third group, significantly less numerous compared to the previous, regarding stress fracture. Stress fracture are common in military and athletic trainess during running, as they often develop forces that are several times higher than their body weight at the interface between foot and terrain.

Military and athletic trainees population are more mainly affected by stress fractures. During training exercises they can develop forces much higher than their body weight at the interface between foot and ground during running [8].

Epidemiology of Different Type of Tibial Plateau Fracture

Several studies show that 52-68% were low energy lesions (level $\leq$ 3) while approximately 32-48% of the lesions were caused by a high energy impact, according to Hohl scales (level 5), Schatzker scale (levels 5 and 6) and AO (levels C1, C2 and C3) [2, 4, 9].

Yang *et al.* observed a particular type of lesion, the fracture of the posterior tibial plateau. Posterior tibial plateau fracture (PTPF) was defined as a fracture with an independent fragment of the posterior column. It is associated especially with high energy lesions (Schatzker levels 5 and 6) with percentages of 51.2 and 76.1%, respectively [10].

Epidemiology of Soft Tissue Lesion Associated

It is now widely accepted that the incidence of soft tissue injuries, such as meniscal tears and ligamentous lesions (ACL, PCL, LCL and MCL), are common, ranging from 47% to 99% [11, 12].

The frequency of soft tissue injury has been found to be in direct correlation with the energy of the initial injury, which often translates to fracture classification.

CHAPTER 2

Tibial Plateau Fractures: Applied Anatomy and Classification

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Abstract: The tibial plateau fractures classification is very important for the clinical prognosis and to plan time and needs for surgery; however, the features of this type of lesion are various, and many classification systems were developed to describe variables that contribute to lesion pattern. It is also important the evaluation of soft tissues that are often involved (compartimental syndrome, exposition), associated knee injuries (meniscal or ligamentous), and general health condition in poly-traumatized patients. The AO/OTA fracture classification system is used by The Orthopaedic Trauma Association as for other fractures. Many surgeons prefer the classification described by Schatzker *et al*. because it is simpler and more familiar. Despite that there is limited inter and intraobserver reliability for Schatzker and AO classifications; future classification systems or revisions of the previous ones will have to consider axial imaging to describe in a better way the fracture patterns.

Keywords: AO classification, Schatzker classification, Tibial plateau fractures classification, Schatzker classification, Tibial plateau anatomy.

INTRODUCTION

As for all site fractures, when we manage tibial plateau injuries we have to evaluate the features of the fracture, associated lesions and possible complications. When we talk about intra articular fractures, the goals of treatment

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include achieving a stable fracture and an anatomic reduction of the joint surface, in order to preserve a functional ROM without need of immobilization after surgery. This result is important also for tibial plateau fractures; despite good anatomic reduction, we can see the development of a post-traumatic arthritis as well, due to the chondral surface injury.

An anatomic, stable reduction can avoid post-traumatic knee arthritis. Tibial plateau fractures may have different patterns, from undisplaced closed injuries treated with no weight bearing, to complex displaced fractures with diaphyseal extension and often soft tissue or neurovascular associated injuries that can affect the lower limb [1]. The fractures of the tibial plateau can involve the articular surface alone or, in more severe injuries, the metaphysis and diaphysis too. At the same time lesions of the tibial spines, tibial tuberosity, menisci and/or ligamentous structures can also be associated. The treatment of the fracture in these types of lesion should be more difficult. Classification systems can help surgeons to understand and treat these types of fractures in order to improve clinical outcomes. In addition, classifications are important for fracture prognosis and for communication between various surgeons when they compare and analyse these injuries.

APPLIED ANATOMY

An optimal knowledge of the site anatomy is important to understand better the fracture pattern and to plan the best treatment for the fracture itself and for the associated lesions. In the proximal tibia the intercondylar tibial eminences are between medial and lateral tibial plateaus. The medial plateau is the biggest one: it is concave in all spazial plane and has an articular cartilage surface thinner than the lateral plateau. This plateau, however, is convex in the sagittal plane and almost flat to slightly convex in the coronal plane. An angle of approximately 3 degrees of varus is formed by the tibial plateau with the long axis of the tibia, so the lateral plateau results slightly higher than the medial one. With a good knowledge of the tibial plateau anatomy, a wrong subcondral or intra-articular screews positioning can be avoided. The tibial spines are a non articular part of the tibial plateau and they are the insertion of anterior and posterior cruciate ligamentous. The footprint of the anterior cruciate ligament (ACL) is more lateral and anterior to the anterior tibial spine.

This area can be multi-fragmentated in high-energy injuries, and although this part is not articular it is important to restore the intercondylar eminence and the anatomy of the proximal epiphysis.

In the knee, the trabecular bone on the medial tibial condyle is stronger than the lateral one because load is predominat in this portion; for this reason a lower energy trauma is sufficient to cause fractures on the lateral side [2]. The intra-articular space between the femoral condyles and tibial plateaus is lied by menisci that are semilunar and triangular-shaped fibrocartilage. It is important to know their normal anatomy because they are often damaged or detached after trauma and we have to repair them during the treatment of tibial plateau fractures. The lateral meniscus is larger than the medial one and covers a larger rate of the lateral plateau. They protect the articular cartilage decreasing from up to 60% on the knee during weight bearing [3]. The anterior horns of these two structures are connected by the intermeniscal ligament and are attached peripherally by the coronary ligaments to the tibial plateaus. In addition, the anterior horn of the lateral meniscus is attached slightly posterior than the medial meniscus.

CLASSIFICATION

History

Palmer in 1951 [4], Hohl and Luck in 1956, and Hohl in 1967 [5] began to classify tibial plateau fractures; they already recognized the major patterns that are today the same for many classification systems for these fractures such as condylar split , subchondral depression, and comminuted bicondylar involvement. Schatzker *et al.* published their classification system in 1979, evaluating the AP radiographs of a series of 94 patients, most of them treated non operatively [6]. Schatzker classification divided tibial plateau fractures into six types: lateral tibial plateau split fracture (Type I), split depression of the lateral tibial plateau (Type II), central depression of the lateral plateau (Type III), split of the medial tibial plateau (Type IV), bicondylar tibial plateau fracture (Type V), and dissociation between the metaphysis and diaphysis (Type VI). The first three types involve only the lateral tibial plateau, Type III (depression) fractures are caused by low-

CHAPTER 3

Evaluation of Tibial Plateau Fractures: The Role of Imaging

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Abstract: Tibial plateau fractures are common injuries and the most difficult of the intra-articular fractures to manage. These fractures are usually related to high energy trauma or osteoporosis in older adults. The fractures normally occur in the 1% in older adults whereas in the elderly at 8%. In case of improper restoration of the plateau surface and the axis of the leg, these fractures could lead to development of premature osteoarthritis, injury in ligaments, as well lifelong pain and disability. The imaging is of paramount importance for assessment of the initial injury, planning management, prediction of prognosis and in the follow-up. Traditionally, the radiological examination was performed with x-rays. Presently, the computer tomography, affiliated with magnetic resonance imaging indicate more accurately the categories of fractures thus facilitating a better surgical plan.

Keywords: Computer tomography, Diagnosis, Imaging, Intra-articular fractures, Magnetic resonance imaging, Osteoporosis, Surgical, Tibial plateau fractures, Trauma, x-rays.

INTRODUCTION

Tibial plateau fractures are one of the commonest intra-articular fracturesresulting from indirect coronal or direct axial compressive forces. Use of technological progress in means of travel have resulted in a heightened number of accidents leading to incidents with complicated fractures.

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Those of tibial plateau are no exception. Being one of the major weight bearing joints of the body, fractures around it are of paramount importance. High energy trauma caused fractures are found in 1% of older adults and in the elderly at 8% rate [1, 2]. Tibial plateau fractures are often complex (estimates suggest that 30–35 % are bicondylar) and commonly occur with associated soft tissue injury [1, 2]. To date thediagnosis and management of complex tibial plateau fractures are acomplicated undertaking to resolve addressed in orthopedic trauma [2, 3]. As with any fracture, the aim of surgery is to restore the normal anatomy, repair soft tissue injuries, and facilitate the return to normal physiological functioning. In this context, the imaging has a central role for assessment of theprimary trauma, determining management and prediction of prognosis.

CLASSIFICATION

Fractures of the tibial plateau include a broad spectrum of fracture patterns. They encompass many and varied fracture configurations that involve the medial condyle (10-23%), lateral condyle (55-70%) or both (11-30%) with differing degrees of articular depression and displacement. A number of classification systems [4 - 10] have been designed to categorize and break down comprehension in clinical practice.

The OTA/AO system [8, 11], the Schatzker classification (Fig. **1**) [9] and the Hohl [5] classification are the systems mostly used in tibial plateau fracture assessment. Thus guidelines are issued for preoperative planning allowing for contrast and comparison in reported findings.

Actually, the fractures of the tibial plateau are typically characterized using the Schatzker system [9], in which fractures are classified as type I–VI. Each increasing numeric category specifies increased level of energy imparted to bone thereby increasing severity of fracture. First four are unicondylar and type V and VI are bicondylar.

In detail, type I is indicated by pure cleavage of the lateral plateau. Type I is found more so in 6% of all tibial plateau fractures in young subjects who have normal bone mineralization.

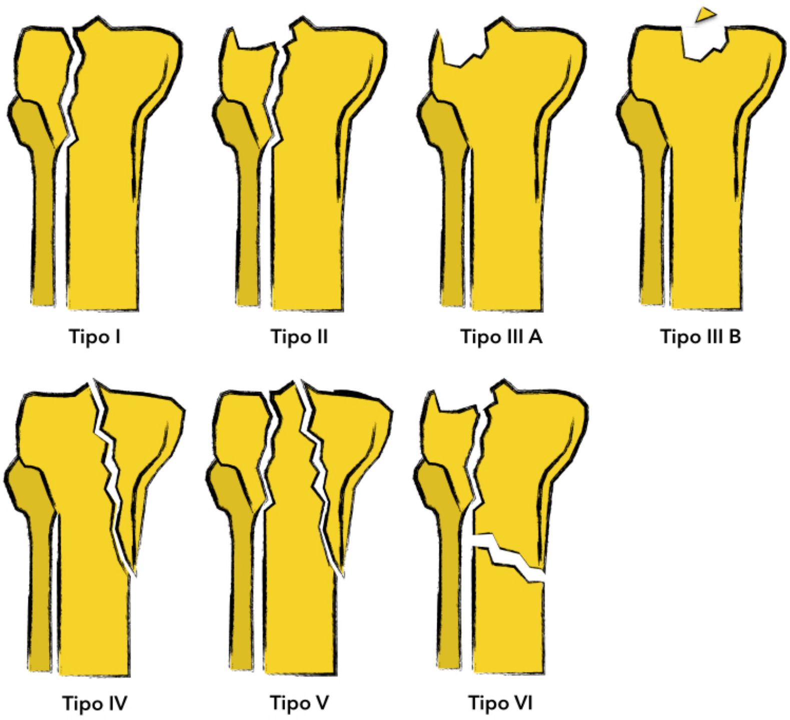

Fig. (1). The Schatzker classification.

Type II is characterized by a cleavage and compression fracture of the lateral tibial plateau, a type I fracture associated with a depressed component. They are found in 25% of all tibial plateau fractures and are notably common in patients in the 4th decade of life or older since a grade of osteopenia is necessary for depression to take place.

Type III is a compression fracture of the lateral tibial plateau in which the articular surface of the tibial plateau is depressed and driven into the lateral tibial metaphysis by axial forces. They are found in 36% of all tibial plateau fractures and typically in middle aged population (the 4^{th} and 5^{th} decades of life) with osteopenia.

Type IV is a medial tibial plateau fracture including a split or depressed part. About 10% of all tibial plateau fractures belongs to type IV category, and are

CHAPTER 4

Conservative Treatment of Tibial Plateau Fractures: Indications and Results

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Abstract: A force over tibial plateau with axial loading and valgus or varus vector can be responsible of tibial plateau fracture. The principles of management include joint congruity, joint stability, and axial alignment and the "personality" of the fracture. It is crucial to recognize, assess and monitor soft tissue swelling. In the present era, the indications for conservative management in form of traction or cast bracing are very few. Anatomical reduction is best achieved with operative modalities, either with closed or open techniques. However, non-operative modalities do hold their importance in certain situations like incomplete or undisplaced fractures, stable injuries, those with osteoporosis, and in patients who are not fit for surgery due to their medical comorbidities. Secondary articular cartilage injuries can be managed depending upon lesion size and activity demands, with simultaneous correction of malalignment and ligament instability wherever needed.

Keywords: Cartilage, Cast, Conservative, Injuries, Management, Nonoperative, Tibial plateau fractures.

INTRODUCTION

Bone fractures with articular involvement have been an important problem since past. Impairment was seen up to varying degrees. According to Charnley [1] in

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1961, anatomic reduction along with early mobilization were the preferred treatment for intra-articular fractures. These objectives were difficult to obtain because of the surgical and fixation techniques available in those times.

Pain, instability, malunion or nonunion were often result of surgery treatment. Greater stiffness was seen with surgery along with plaster immobilization, than plaster immobilization alone. Added surgical trauma and the periarticular location of the fixation device [2 - 4] was thought to be the cause of stiffness after surgery. Conservative treatment was so generally indicated for treatment of articular fractures and surgery was considered the last resort. Conservative treatment strategy included accurate evaluation, than fracture reduction and immobilization and finally rehabilitation. Joint stiffness was seen invariably during rehabilitation after fracture union. Apley encouraged early joint rehabilitation by "successful methods of traction to permit early motion of joints, while providing sufficient immobilization for the fracture union" [5, 6]. First results in tibial plateau fractures management with this technique were satisfactory, but not reproducible because tibial plateau fractures were not classified [6]. The new concepts by the AO group of atraumatic techniques of open reduction and internal fixation (ORIF) brought about a revolution in fracture surgery [4, 7 - 9]. However, with the increase in trauma energy (car accident, sport trauma), soft tissue injuries also increases. High-energy fracture types (Schatzker IV, V, and VI) were often treated with large surgical approaches and internal osteosynthesis through a tenuous soft tissue envelope. This led to high complication rates, with reported 50 percent in some studies [4, 10 - 15]. The time tested conservative treatment is now mainly indicated for stable and undisplaced tibial plateau fractures, or with fractures with excessive comminution, or advanced osteoporosis. It might be also the only treatment option available for a patient who is medically unfit for surgery. When chosen, near anatomical articular congruity should be attained along with normal alignment and early mobilization, to prevent compartment overload and future osteoarthrosis [16 - 19]. The concept of staged fixation is now favourable. With significant soft tissues compromise, immediate open surgical treatment can be dangerous. An external fixator initially can span through the zone of injury and overall limb realignment and stabilization is achieved. When the soft tissues have recovered sufficiently, "delayed fixation can be accomplished through a safe operative corridor of healthy tissues" [6].

INDICATIONS FOR CONSERVATIVE TREATMENT

Prognosis of proximal plateau injuries depend upon: (1) depth cartilage depression, (2) fracture fragmentation (3) fracture comminution and dissociation [3, 10, 20 - 25], and (4) extent of the soft tissue damage [21, 26 - 28]. Conservative treatment is indicated for low-energy undisplaced tibial plateu fracture or for stable lateral plateau fractures, and for some osteoporotic patients. Severe comorbidity of the patient can be a good indication for conservative treatment [6].

Instead, some authors state that articular cartilage depression from 4 to 10 mm is tolerable; depression over 10 mm is cause of instability and early osteoarthritis [5, 10, 13, 17, 22, 23, 29 - 40, 42]. Closed reduction (manipulation and traction) is not able to correct impacted articular fragments. Pauwels [41] demonstrated that "an incongruence of less than 1.5 mm appears to result in no significant increase in contact pressures". However, weight bearing increases stress rise in case of axial malalignment [42]. Mitchell and Shepard [43] showed that "malreduction and instability result in rapid articular cartilage degeneration". A correct reduction without contact over-pressure between femoral condyles and tibial plateau is an important factor for long term prognosis [22, 36]. Rasmussen [4] showed a "high correlation between post-traumatic osteoarthrosis and residual condylar widening or discontinuity between the tibial plateau surfaces and the femoral condyles".

The radiographic aspect of osteoarthritis does not always correlate with the clinical state [17]; however, it's fundamental to achieve anatomical reduction and stability to prevent compartment overload by correcting any coexistent axial malalignment.

Kettlekamp and co-workers suggested that "a major factor in determining functional outcome is the maintenance of the correct mechanical axis at the knee. A decrease in joint surface area and a rise in stress resulting from the deformity and the increase in axial loading may lead to post-traumatic osteoarthrosis" [16, 18, 32]. Sometimes, in case of high energy fracture, anatomic joint reconstruction is impossible to achieve If the metaphyseal and diaphyseal components are

CHAPTER 5

Knee Arthroscopy and Tibial Plateau Fractures

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Abstract: Arthroscopic-assisted fluoroscopic treatment of tibial plateau fractures has gained popularity in the last decade and is now indicated as one of the treatments of choice in Schatzker types 1, 2 and 3 fractures; it ensures optimal reduction and a stable fixation with plate or cannulated screws may be performed after reduction. In selected type 4 fractures arthroscopy may allow an evaluation of articular fracture reduction, thereby obviating the need for extensive arthrotomy. This chapter aims to review the technical points that are useful to the successful video-assisted management of tibial plateau fractures.

Keywords: Internal fixation, Knee arthroscopy, Tibial plateau fractures.

BACKGROUND

Arthroscopic-assisted fluoroscopic treatment is a minimally invasive alternative to standard open surgical techniques for tibial plateau fractures [1, 2]. The possible advantages are less postoperative swelling than open techniques and reduction of pain, risk of complications and recovery times. Several fractures patterns may be treated with this techniques but a rigorous indication should be respected.

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INDICATIONS

Many classification systems have been developed for proximal tibial fractures but the classification system proposed by Schatzker is the most widely used nowadays [3]. Its success relies on its clinical viability, it considers two fundamental lesions: cleavage and depression, along with their possible combinations. According to the Schatzker classification fractures type 1 (lateral split), type 2 (lateral split with depression) and type 3 (pure depression of the lateral plateau) are good indications for arthroscopic-assisted fluoroscopic treatment (Fig. **1**), In selected type 4 (medial plateau fracture with or without an intercondylar fracture) this technique may be used but invasive internal fixation erases several of the benefits from arthroscopic treatment, making percutaneous fixation a more reasonable choice in this type of fracture when treated with the arthroscopic method. However, extensive fixation may be warranted in the event of a comminuted fracture and in patients with osteoporosis. In type 5 (bicondylar fracture) and type 6 (unicondylar or bicondylar tibial plateau fracture with an extension that separates the metaphysis from the diaphysis) arthroscopy does not add advantages in respect to common open reduction and internal fixation.

BENEFIT AND RISKS

Arthroscopic-assisted fluoroscopic treatment presents many benefits: it allows to irrigate the joint, to remove loose bodies and/or free fragment and to treat associated soft tissue lesions. Associated meniscal tears is frequent in those cases, in literature its incidence varies from 2% to 47% [4, 5] and (in selected cases) meniscal suturing may be (indicated) appropriate whenever achievable, due to the reported high healing rate and the osteoarthritis risk intrinsically associated with the injury [6]. Lesions of the collateral ligaments is less common but should be sought routinely, as they may compromise knee stability and sometimes require surgical repair during the fracture fixation procedure. Damage to the anterior cruciate ligament (ACL) is common and reported in 4% to 32% of the cases [7, 8]. Schatzker types 4 and 6 fractures are more likely to have a ACL associated lesion [9]; it is generally preferred to treat bony avulsion at the same time as the tibial plateau, while midsubstance injury requires a second stage reconstruction, if indicated [10, 11]. Posterior cruciate ligament (PCL) lesions are less common.

Direct vision of the reduction and the chance of clinically testing the stability of the fracture are the most important advantages of this technique.

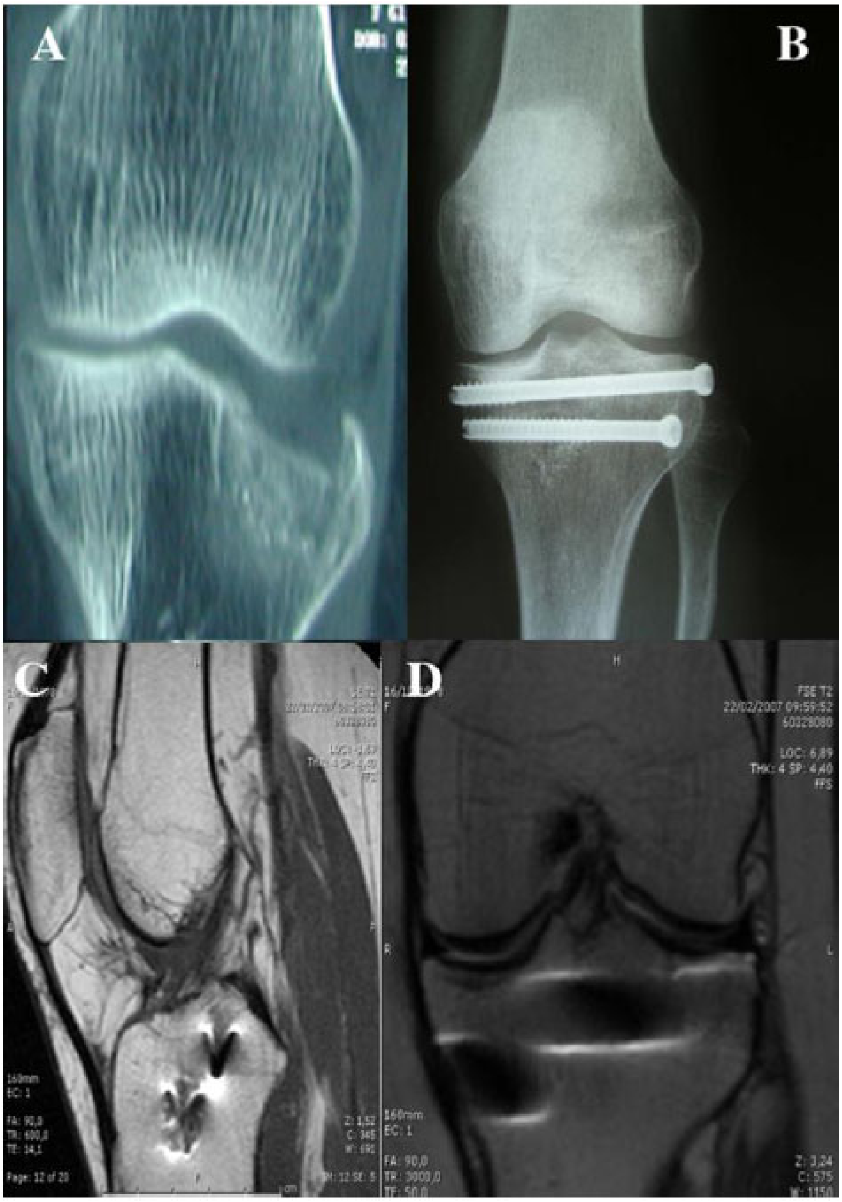

Fig. (1). Preoperative CT scan (**A**), post-operative X-rays (**B**) and MRI (**C** and **D**) images of a Schatzker type III fracture treated with arthroscopic assisted reduction and internal fixation [courtesy of dr. Francesco Atzori, San Luigi Hospital of Orbassano, Italy]).

CHAPTER 6

Balloon Tibioplasty

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Abstract: The target of tibial plateau fracture management is to obtain an anatomical reduction and an early knee mobilization. Balloon tibioplasty is a new minimally invasive technique adapted for reduction of depressed tibial plateau fracture and it represents a surgical method to restore the cartilage surface. The advantages of balloon tibioplasty are: minimally invasive technique and creation of symmetric space inside the proximal tibia bone that reduces stresses on the fracture. The bone gap above the tibia plateau is filled with ceramic bone cement through a small cortex bone window. It is a technique that requires a correct learning curve, but it may be a useful tool that makes the reduction of selected depressed tibial plateau fractures easier.

Keywords: Articular fractures, Balloon, Fixation, Osteoplasty, Tibial plateau, Tibioplasty.

INTRODUCTION

The tibial plateau fractures are intra-articular fractures and they are divided into high and low energy lesions. They are often associated with ligament injuries and secondary long-term complications are frequent (*e.g*. post-traumatic arthrosis and a valgus deformity). Nowadays surgeons pay more attention to soft tissues preservation [1]. Mini-invasive techniques have reduced long-term complications and they are able to preserve the normal functions of the knee [2, 3]. The main target of these techniques is to restore the articular surface the most anatomically

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as possible, preserving the stability and the load axis of the knee [4].

ETIOLOGY

The tibial plateau fractures are often due to a trauma with a direct axial load, more commonly in valgus stress position [5]. The femoral condyle transfers the load directly on the tibial plateau. Injury types are related to the position, the longitudinal axis and the flexion degree of knee. The lateral tibial plateau is more involved than the medial one and it is correlated to the axis of the knee (usually valgus) [6]. Many other factors influence the etiology of the lesion, such as the age [7, 8] and bone quality of the patients. Ligament and capsular injuries are commonly associated to bone fractures in younger, because of the cancellous bone is more resistant than that in elderly patients [9].

DIAGNOSIS

Radiographic evaluation involves standard AP and LL image. Additional oblique projection are useful to better determinate the fracture [10]. CT Scan with 3D reconstructions has increased the accuracy of diagnosis and the fracture tridimensional study [11]. Moreover MRI evaluates soft tissue associated injuries in a non-invasive way compared to arthroscopic study [12].

CLASSIFICATION

Many classification scores have been proposed. Currently the most widely used is the classification proposed by Schatzker. It is the first classification that divides medial and lateral plateau fractures. The I type is a lateral fracture with one bone fragment, the II type is a splinted fracture associated with depression of the plateau. The III type is a pure central depression, while condyles are intact. The IV type involves medial plateau and it is divided in to two subgroups: type A is a split-fracture and type B is a fracture with depression of the bone. The V type is an inverted "Y" fracture that involves both tibial condyles, without metaphysis or diaphysis fragments. The VI and last type is a complete fracture between metaphysis or diaphysis segments [13]. Other classifications commonly used are: the Hohl scoring system (the first that have been proposed), Moore and AO scoring system [14, 15].

BALLOON TIBIOPLASTY

The common fracture patterns encountered are split depression (OTA Type B3, Schatzker Type II) and lateral depression injuries (OTA type B2, Schatzker type III) in elderly patients, due to osteopenia or osteoporosis. The bone depression needs to be elevated through a surgical made bone window in the proximal tibia without opening the joint. The tibial plateau is covered by hyaline cartilage that can be damaged easily; every mini-invasive surgical approach may lead to an intra-articular penetration.

Pizanis *et al*. described a mini-invasive technique: he used an inflatable kyphoplasty balloon as a reduction aid. It allows to minimize the cortex bone window and increases the mechanical force needed to elevate the depression.

Pre-Operative Planning

A correct pre-operative planning is very useful to determinate the type and the deepness of the fracture. Standard AP and lateral radiographs should be associated with CT scan to determinate correctly the landmarks, which are the tibial spine and the head of the fibula. It is important to evaluate the cartilage surface and the posterior part of the lateral tibial plateau. Using standard fluoroscopic study (AP and lateral projections), the introducer should be placed between 2 to 10 mm below the deepest part of the fracture.

Surgical Technique

The patient is placed in supine position with the knee flexed at 45 degrees. The surgical skin incision is a limited exposure of the lateral proximal tibia. Arhtroscopy is useful to evaluate the articular surface; in case of difficult evaluation of the articular joint, a small transverse arthrotomy could be performed. Using minimally invasive techniques a fragment locking T-plate locked with cortical screws (Synthes, Freiburg, Germany) is placed on the antero-lateral surface of the proximal tibia as a lateral support. An assistant prepares the balloon (IBT) on the back table at the beginning of the surgery. The skin incision is performed on the medial side of the tibial plateau. The Osteo Introducer (Kyphon, Sunnyvale, CA) is composed of an external cannula, a spindle with an

CHAPTER 7

Open Reduction and Internal Fixation of Tibial Plateau Fractures

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Abstract: Surgical fixation of tibial plateau fractures is technically challenging, carrying significant risks of complications for both patient and surgeon. A detailed understanding of the knee joint, coupled with classification of tibial plateau fractures, allows for accurate pre-operative planning and appropriate patient selection, resulting in the best possible outcome for patients. Open reduction and internal fixation of such fractures is done with the aim of restoring alignment, native articular surface of the knee, preventing early onset osteoarthritis. This chapter will explore the various surgical approaches described when approaching the tibial plateau, outlining the merits and drawbacks of each when undertaking open reduction and internal fixation of tibial plateau fractures.

Keywords: Approach, Fixation, Open, Osteosynthesis, Plateau fracture, Reduction.

CLASSIFICATION OF FRACTURES

Accurate classification of tibial plateau fractures allows for consistent clinical communication among surgeons, and appropriate formulation of treatment plans. Classification systems allow for documentation of soft-tissue damage, fracture location and extension pattern, all helping to guide treatment and the most appropriate surgical approach [1].

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The most common classification system used is the Schatzker classification [2].

Schatzker Type I

Schatzker Type I fractures are involving the lateral tibial plateau, resulting in a wedge shaped fragment displacing laterally and downwards [2, 3].

Schatzker Type II

Schatzker Type II fractures involve a wedge split from the lateral tibial plateau, combined with a comminuted fracture of the plateau with metaphyseal bony depression [2, 3].

Schatzker Type III

Schatzker Type III fractures are central depression fractures of the tibial articular surface, with an intact lateral cortex [2, 3].

Schatzker Type IV

Schatzker type IV is a fracture of the medial tibial plateau, either a split wedge fragment or a depressed comminuted fracture. Type IV fractures can also involve the tibial spine, and are associated with neurovascular compromise and ligamentous damage of the knee [2, 3].

Schatzker Type V

Schatzker Type V fractures represent bicondylar fractures involving the medial and lateral tibial plateau, and may involve the intercondylar area [2, 3].

Schatzker Type VI

Schatzker VI fracture is a bicondylar tibial plateau fracture, however there is dissociation of the diaphysis from the metaphysis. This type of fracture is associated with significant articular surface disruption and soft tissue damage [2, 3].

PRE-OPERATIVE CONSIDERATIONS

There are few circumstances in which immediate surgery is indicated for a tibial plateau fracture. However, such cases include open fractures, vascular compromise and the presence of compartment syndrome [4]. In the absence of these, surgical planning is dictated by the extent of soft-tissue damage. Physical examination, and when indicated further detailed imaging with Computed Tomography, are core components of pre-operative planning [1].

INTRA-OPERATIVE CONSIDERATIONS

Surgeon preference dictates patient positioning on the operating table. Typically, the patient is supine, unless a posterior approach is indicated [2]. A high riding tourniquet is placed on the thigh. The knee is flexed to at least 30° or can be left "hanging" off the table, allowing for release of the collateral ligamentous structures [1, 3, 4].

The use of a C-arm image intensifier intra-operatively is common practice, allowing for assessment of fracture reduction and implant placement. The C-arm image is typically placed on the contra-lateral side and should be sterile prepped prior to commencing surgery [1]. Concurrent arthroscopy can be considered, as it enables direct visualization of the meniscus and articular surface of the tibia. A femoral distractor may be utilized for surgical reduction of tibial plateau fractures, allowing for up to 0.5-1.0cm distraction of the joint. Manual traction is also used, but requires additional assistants, and would not provide an accurate fracture reduction and stable surgical field [1, 4].

Implant choice is vast and varied in the current market. Commonly, 'L' and 'T' plates are used in surgical fixation of both lateral and medial plateau fractures with cannulated screws [5]. Recent contoured plate designs facilitate cortical screw usage in locking and non-locking systems, allowing for support in comminuted fractures of the articular surface [4, 5]. Complex high energy fractures involving the metaphysis may require a bridging plate when fixing the lateral or medial plateau, to achieve adequate fixation of the condyles to the shaft of the tibia [6].

CHAPTER 8

Damage Control Orthopaedics and the Role of External Fixation in Tibial Plateau Fractures

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Abstract: The plateau tibial fracture is a challenging pathology where associated lesions can complicate by far the fracture treatment. External fixation could be a valuable option, both in the emergency stabilization and in the definitive synthesis, especially when general or local patient's conditions demand for a tissue sparing approach. This chapter is divided in two, the first part talks about the indications and the technical rules of the bridging external fixators and the clinical applications of Damage Control Orthopedics (DCO) to tibial plateau fractures. The second part is focused on those complex (because of the soft tissue envelope conditions or the fracture pattern) lesions that could take advantage of a definitive treatment based on the external fixation, more frequently circular. Technical and mechanical characteristics, indications, surgical application, pros and cons of the circular frames are described.

Keywords: Damage control, External fixation, Fractures, Reduction, Soft tissue injuries, Tibial plateau.

INTRODUCTION

The knee joint and the tibial plateau, differently from the hip, but similarly to the ankle, lie under a relatively poor soft tissues coverage [1].

Fractures of the plateau can be up to major trauma, such as motorbike accidents or falls from height, as to lower energy traumas, such as the knee twisting very common in skiers.

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The conditions of the soft tissue surroundings are very important in planning the therapy strategies. Very often the fracture is open, but even when it is closed, the poor conditions of the soft tissue envelope can be a severe threat to the functional outcome. The incidence of open tibial plateau fracture appears to be relatively low if considering all fracture patterns (4.8% in a revision of 8,426 patients with monolateral tibial plateau), but it can increase dramatically when we focus on more challenging casuistries, depending on high energy traumas (13 open fractures out of 31, grade-IIIA according to the Gustilo-Anderson classification, being the remaining 18 closed fractures characterized by severe soft tissue lesions, Tscherne and Oestern grade 2/3, in a recent series) (Figs. **1, 2**) [2, 3].

Fig. (1). N. C., male, 30 yrs., right leg badly crushed by a car in motorcycle accident (December the 9th 2012): severe bone loss (about 9 cm), skin degloving, huge soft tissue mangling (open fracture Oestern and Tscherne grade III or Gustilo-Anderson IIIA), tibial plateau fracture AO 41.B3.1 or Schatzker II (split with depression). AP view.

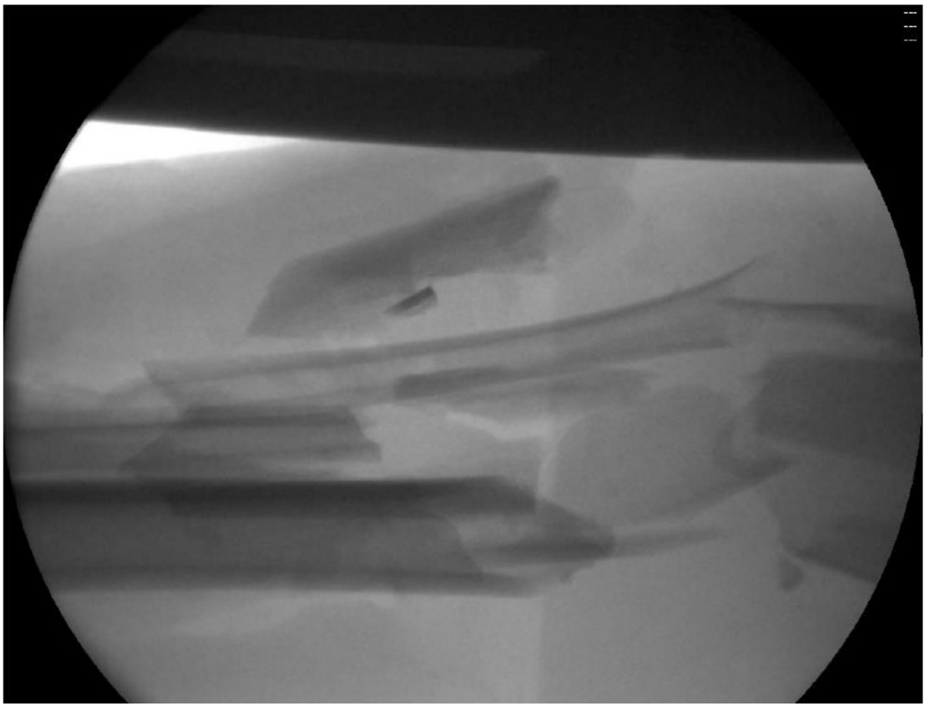

Fig. (2). Lat. view.

When the trauma energy is higher, there is the possibility for the tibial plateu fractures to be associated with other injuries (53/239, 22.6% in a Brazilian casuistry) [4].

Tibial plateau fractures, closed or open, especially when involving the medial side (Schatzker IV/VI), represent a risk factor for arterial injuries [5]. Serious implications of these fractures could be the nerve injuries, especially the peroneal nerve, and the compartment syndrome [6, 7].

The aim of the surgical treatment is the functional recovery of the painless knee function through the anatomical reconstruction of the joint surface and the axial and torsional restoration of the tibial shaft. The amount of residual acceptable articular depression and dyaphiseal dislocation is still far to be widespread accepted [8].

Open reduction and internal fixation (ORIF), ensuring precocious motion through

CHAPTER 9

Diagnosis and Treatment Strategy in Associated Lesions of Tibial Plateau Fractures

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Abstract: Tibial plateau fractures are associated with a broad spectrum of injuries. Associated soft tissue injuries in tibial plateau fractures can be divided as soft tissue envelope lesions, neurovascular injuries and intra-articular lesions. Careful preoperative soft tissue envelope management is important in avoiding additional injury. The neurovascular status of the extremity must be evaluated, although concomitant injuries of neurovascular structures are rare. Lesions of the ligaments and/or the menisci has been reported in several studies and may contribute, if not properly treated, to the substandard outcomes associated with this type of fractures. Traditionally, meniscal tears are reported in 20-50% cases of all the tibial plateau fractures, while ligaments lesions are reported in 10-30%. Even if the examination of knee stability and of the conditions of menisci and ligaments is not so easy, is recommended to perform a careful evaluation of the patient in order to determine associated ligamentous damage. The imaging studies routinely performed for tibial plateau fractures are plain anteroposterior and lateral radiographs and three-dimensional CT, while MRI has not yet become a standard tool. The final outcome of surgical treatment may be influenced by associated lesions of the menisci or of the knee ligaments. There is a wide uniformity of behaviours in treating meniscal tears: central tears in white zone must be resected, while peripheral lesions in red zone and meniscocapsular disjunction must be repaired. Ligamentous injuries associated with bony avulsion should be acutely treated during fracture fixation; in the absence of bony avulsion, functional and residual laxity should be addressed at a later date.

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Keywords: Bony avulsion, Ligamentous injuries, Meniscal tears, Repair, Soft tissue.

INTRODUCTION

Tibial plateau fractures represent just 1% of all fractures [1 - 7], but they could have severe consequences if the broad spectrum of associated injuries is not diagnosed and treated properly. The traumatic mechanism (the amount of the force, the position of the limb during the trauma [8]) and the degree of osteopenia [9, 10] determine not only the fracture type, but the extent of soft tissue injury too. Damages of the soft tissue in tibial plateau fractures (injuries to the cruciate and collateral ligaments, the menisci, arteries and nerves) have been reported [1]. They can be divided as soft tissue envelope lesions, neurovascular injuries and intra-articular lesions. The marginal soft tissue envelope lesions affect the skin and subcutaneous tissue surrounding the proximal tibia. The neurovascular injuries affect the popliteal neurovascular bundle and the common peroneal nerve. The intra-articular lesions affect the intra-articular structures of the knee, basically menisci and ligaments. They are the most frequent associated lesions in tibial plateau fractures.

SOFT TISSUE ENVELOPE LESIONS AND NEUROVASCULAR INJURIES

To achieve a good outcome in complex tibial plateau fracture it is mandatory to evaluate and correctly treat any associated soft tissue lesion. This tissues are often involved in high-energy knee trauma because of the thickness of subcutaneous tissue, making it vulnerable both from the inside (displacement of bone fragments) and from the outside (direct external forces). Involvement of soft tissues around the knee increases the risk of complications following the treatment of high-energy knee trauma [11]. The physical examination should always include a thorough assessment of the soft tissue envelope. In fact, an high energy trauma should cause cutaneous and subcutaneous damage, venous and nervous compromise, increasing the risk of early and late complications [11, 13, 14]. Severe soft tissue injuries may not allow primary plating of the fracture, requiring instead the use of a spanning external fixator [12]. In the case of an open fracture, when the soft tissue envelope is completely disrupted, cleansing of the open wound is required, followed by a complete coverage of the bone segment of the tibia, reducing future risks of infection [13]. The acute treatment of soft tissue injuries consists in reducing as much as possible the inflammatory response, using NSAIDs and cryotherapy, and immobilizing the knee using splints, transkeletal traction or external fixators [15 - 17, 19]. Splints are usually used in fractures without a severe soft tissue impairment, because they require a circumferential dressing that reduce the possibility of a constant evaluation of the skin. In high energy trauma it is preferable to use a transkeletal traction or a temporary knee-spanning external fixator, with the aim of achieving a fracture reduction by the process of ligamentotaxis [11] (Fig. **1a-b**) .

Fig. (1). Temporary placement of knee-spanning external-fixator for a Schatzker VI tibial plateau fracture in a high-energy trauma.

CHAPTER 10

The Role of Primary Total Knee Arthroplasty (TKA) in Tibial Plateau Fractures

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Abstract: Total Knee Arthroplasties (TKAs) in tibial plateau fractures can be performed in the acute or chronic settings. Treatment of tibial plateau fractures with Open reduction and Internal Fixation (ORIF) in elderly patients can lead to poor results because of poor bone quality, fracture complexity and higher risk of complications. For these reasons primary TKA in the acute setting can be an option in elderly patients. Most of the authors agree in confirming that this is a safe treatment with good clinical outcomes, but inferior compared to whom obtained in elective TKAs, with a higher risk of complications, similar to those reported in revision TKAs. On the other hand ORIF is the gold standard treatment in tibial plateau fractures in younger patients, but the incidence of post-traumatic arthritis is high, with the need of TKA conversion. There are few reports on literature on TKAs performed after tibial plateau fractures, but there is agreement in affirming that clinical outcomes and implant survival in those cases are lower than in TKA performed for primary arthritis. In this chapter we will analyze the indication for primary TKR in tibial plateau fractures, both in acute and chronic setting, with a literature review on the clinical outcomes.

Keywords: Arthritis, Arthroplasty, Elderly, Fracture, Knee, Post-traumatic, Tibial plateau.

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INTRODUCTION

The tibial plateau fractures represent 1-2% of all fractures, with an annual incidence of 13.3 per 100000 in the adult population; however approximately 50% of those fractures occur in patient older than 50 years old, with 8% to 24% occurring in elderly. In the elderly those fractures can result from a low energy trauma, with greater prevalence in man (male female ratio 54:46) [1]. The goals of treatment in these cases are: 1) pain control, 2) early mobilization, 3) restoration of function and 4) minimizing the need for further surgery. In young patients Open Reduction and Internal Fixation (ORIF) is the gold standard [2]. In some cases primary Total Knee Arthroplasty (TKA) may play a role in tibial plateau fractures treatment. In this chapter we will analyze the role of TKA both in the acute and chronic setting, in association to indication, surgical technique and results.

ACUTE SETTING

Introduction

ORIF is often the treatment of choice in tibial plateau fractures [2]. However there is still a concern in using ORIF in elderly patients, because of poor bone quality, fracture complexity and higher risk of complications [3]. Honkonen underlined the difficulties to obtain a stable fixation in elderly patients, in association to the high risk of losing reduction despite stable internal fixation and bone grafting [4]. Although poor fixation may be improved with newer angle-stable plate, adequate reduction remains challenging. Besides soft tissue stripping needed for ORIF may lead to wound healing problems. Finally most type of fracture fixation do not allow immediate post-operative weight-bearing [5]. For those reasons some authors described an unacceptable failure rate (79%) and unsatisfactory results for ORIF in elderly patients [6].

The main complications reported on literature for ORIF are loss of fixation, post-traumatic arthritis requiring TKA, malunion or nonunion, stiffness and medical co-morbidities secondary to immobilization. Besides TKA in patients with previous tibial plateau fractures is challenging because of the difficulty ligament balancing, extensor mechanism scars, patellar maltracking and the need to restore a better lower limb alignment. 26% of complications have been reported for TKAs in patients with a previous tibial plateau fracture, with a reoperation rate of 21% [7]. Those complications, associated to the need of early mobilization, have led several authors to recently suggest the use of TKA for acute treatment of tibial plateau fracture in elderly [3, 8 - 13]. Primary TKA in tibial plateau fractures seems to have better functional outcomes, better survival and lower complications rate if compared to ORIF in the elderly, also if the results cannot not achieve those obtained with TKA in primary osteoarthritis [3].

Indication

Primary cemented TKA may be an option in acute treatment of elderly patient affected by proximal tibial fractures due to previous osteoarthritis, with the main advantage of early mobilization compared to ORIF. However, mechanical failure, loosening and periprosthetic fractures are still a concern; for these reasons it should be reserved to elderly sedentary patients [14]. Surgeons should take in consideration managing acute tibial plateau fracture with TKA in patients with pre-existing arthritis, who are unable to comply with restricted weight-bearing, with comminuted type C intra-articular fractures and in patients in whom a secondary procedure is best avoided [8]. A relative contraindication to primary TKA in tibial plateau fracture is avulsion of the tibial tubercle, because nonunion of this fragment after TKA is really demanding to manage [3, 15].

Pre-Operative Planning

In acute trauma the pre-operative planning is more difficult compared to elective TKA, because there are no weight-bearing X-rays, so the radiological alignment is difficult to evaluated. Antero-posterior and lateral x-ray on rest are mandatory; Computer Tomography (CT) scan is really useful to classify the fracture morphology and to identify the amount of bone losses [16]. Clinical evaluation of medial-lateral instability is fundamental to help the surgeon in deciding the grade of constrain, that should be planned pre-operatively [8].

Surgical Technique

There are few differences in elective or acute trauma TKA in terms of surgical

CHAPTER 11

Rehabilitation After Tibial Plateau Fractures

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Abstract: Tibial plateau fractures are common and severe joint lesions which usually require surgical fixation. They may cause severe postoperative pain and require long hospitalization to provide effective analgesia and to start an appropriate rehabilitation. Specific programs of post-operative rehabilitation are necessary for acceptable recover. Nowadays, well established specific rehabilitation protocols do not exist and treatment is often experience-based. This chapter focuses on physical therapy and on the rehabilitation techniques after tibial plateau fractures; also, it evaluates the effectiveness of the most common techniques.

Keywords: Physical therapies, Physiotherapy, Recover, Rehabilitation, Tibial fracture.

INTRODUCTION

The tibial plateau fracture may take up till 4 months for complete consolidation and it may require up to 6 months or, sometimes, more time to return to the same pre-clinical activity level. This aspect becomes more important when considering that this kind of fracture often happens to socially and working active persons [1]. As described in the previous chapters, fractures of the tibial plateau range from simple undisplaced fractures to complex articular lesions.

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The choice of the kind of treatment is a subject for trauma surgeons and obviously it affects the clinical outcome as well as the rehabilitation program. However, the aims of rehabilitation are the same either after conservative and surgical approach, with only a few of specificities: to recover as quickly and as completely as possible the daily activities and, when required, the sport ones.

Since persons with tibial plateau fractures belong to various age brackets with very different demanding (the need of a quick walk for the elderlies and of starting again competitions for the professional sportive patients, respectively) the rehabilitative treatment must be case-specific, based on the characteristics of the patient and on the kind of orthopedic treatment. All these facts underline the importance of the specialist in the rehabilitation for the treatment of a fractured knee: he must consider globally the patients, their clinical situation, co-morbidities, the surgical results and, last but not least, the patient's expectations and goals. Along with the work of the physiotherapist, continued medical surveillance is necessary to evaluate the needs and the progresses of the patient and also to detect as soon as possible any complications.

The rehabilitation program should begin immediately after surgery or after conservative treatment [2] with the following objectives: 1) to control edema and pain, 2) to maintain a correct muscular strength on both legs, 3) to maintain the range of movement of hip and ankle. However, weight bearing and mobilization of the knee are the two key points in the whole rehabilitative process. Since these items are definitely established by the surgeons, an effective and continue collaboration between the medical specialists is greatly recommended to set the timing and the goals of the specific work on the injured knee.

Knee mobilization must be started as early as possible: usually it is authorized by the surgeon, according to the stability of the fracture and the bone quality. When a knee can be mobilized, the Rehabilitation specialist will establish a specific program with the following goals:

1. Progressive recovery of:
    a) range of movement of the knee,
    b) proprioception,

c) muscular strength;

2. Partial and progressive weight bearing on the affected side (usually after 2-3 months according to orthopaedic indications)
3. Recovery of the correct walking pattern (initially with crutches)
4. Recovery of the maximum grade of autonomy in the ADL;
5. Possible return to the previous sport activity.

The immediate identification and treatment of possible serious complications is mandatory (see Red Flags)

It must be considered, that the majority of persons with severe tibial plateau fractures could not come back to their previous level of activity. So patients' awareness is mandatory, specially for the ones playing competitive sports, as this injury could represent a career ender [3]. Overall, a post-injury shift toward activities with less impact has been reported for the majority of people.

Red Flags

- *Non controlled pain*
- *Contention intolerance*
- *Deep-Vein thrombosis*
- *Compartment Syndrome*
- *Infections*
- *Peripheral neurological deficits*

REHABILITATION APPROACH AFTER SURGICAL TREATMENT

Rehabilitation approach can be divided in 3 steps with different goals and programs:

1. Post operative phase: control of pain, reduction of edema, mobilization of other joints.
2. Rehabilitation before the concession of weight bearing: passive and assistive – active mobilization of the injured knee, increasing gradually the range of movement [4], exercises to recover/maintain muscular tono-tropism, treatment of the surgical scar and fibrous adhesions. Walking with crutches.
3. Rehabilitation after the concession of weight bearing: progressive restart of

Appendix

ACCP = American College of Chest Physicians
ACL = Anterior Cruciate Ligament
ADL = Activity Daily Life
AO = Arbeitsgemeinschaft für Osteosynthesefragen (Association for the Study of Internal Fixation)
AP = Antero-Posterior
ARIF = Arthroscopic Reduction Internal Fixation
ASA = American Society of Anaesthesiologists
CRPS = Complex Regional Pain Syndrome
CT = Computerized Tomography
DCO = Damage Control Orthopaedics
DVT = Deep Venous Thrombosis
G-A = Gustilo-Anderson
IKDC = International Knee Documentation Committee
IKS = International Knee Society Rating System
K-WIRES = Kirschner Wires
LCL = Lateral Collateral Ligament
MCL = Medial Collateral Ligament
MDCT = Multiple Detector Computed Tomography
MRI = Magnetic Resonance Imaging
OA = Osteoarthritis
OTA = Orthopaedic Trauma Association
ORIF = Open Reduction Internal Fixation
PCL = Posterior Cruciate Ligament
ROM = Range of Movement
TA = Tibialis Anterior Muscle
TKA = Total Knee Arthroplasty
TKR = Total Knee Replacement

SUBJECT INDEX

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