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Appropriateness of fixation use in tibial plateau fractures

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Summary

The appropriateness of fixation use in orthopedic surgery is a debated and constantly evolving topic, similar to the devices themselves. Devices and materials impossible even to imagine until a few years ago, are now available. Consequently, indications, timing and methods of surgical treatment are constantly changing, along with the expansion of knowledge and technological progress. This also applies to the treatment of tibial plateau fractures which, due to the specific anatomy of the knee joint and the traumatic mechanisms, represents a constant challenge for surgeons. In addition to the fracture typology, several factors must be considered, among which, undoubtedly, the degree of soft tissue injury. Age, functional demands, patient compliance, and comorbidities must be carefully evaluated before choosing suitable osteosynthesis devices, i.e., cannulated screws, synthetic bone substitutes, the assistance of arthroscopy technique (ARIF) in closed reduction internal fixation (CRIF) and in minimally invasive percutaneous plate osteosynthesis (MIPPO), support plates and locking plates in open reduction internal fixation (ORIF), temporary or permanent external fixators (TEF) and, finally, primary total knee arthroplasty (PTKA), which in recent times have been proposed for treating complex fractures in the elderly with poor bone quality and severe pre-existing knee arthrosis.

Key words: appropriateness, fixation, tibial plateau fracture

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Introduction

Choosing appropriate fixation for the fracture treatment consists in selecting the most suitable surgical procedure by evaluating, in addition to the type and "personality" of the fracture, all the patient's general and local issues, in order to obtain the best result in a specific clinical case. Among the general problems, clinical stabilization of the patient and the treatment of any serious vascular lesion have to be addressed with high priority. Next, the patient's age, functional demands, compliance, and possible presence and significance of comorbidities must be evaluated.
Among the local factors to be taken into account, the focus is on the soft tissue condition, which, given the thin thickness of the subcutaneous tissue surrounding the knee joint, are significantly exposed to injuries from external agents (direct trauma) and from internal agents, such as the bone fragments themselves (indirect trauma).

Generalities

Tibial plateau fractures are common traumas. They represent 1.2% of all fractures and their occurrence is increasing[1]. The most affected ages are the decades between the 40s and the 60s; these fractures are infrequent in the very young and rare in the elderly. The most affected gender is the male one. The particular morphology of the

tibial plateau entails a load distribution representing one of the most complex of the human body and makes the tibial plateau fractures extremely critical for the articulation and stability of the knee. The most frequent injurious mechanism is due to a stress in valgus, with or without load exerted along the longitudinal tibial axis, with the consequent fracture of the lateral tibial plateau, more frequent than that of the medial plateau. Traumas are customarily divided into high-energy and low-energy. High energy traumas are mostly due to traffic accidents, and more rarely to falls from above or to sports injuries. They can be monocondylar affecting the medial column, or bicondylar, affecting the three columns simultaneously. Low-energy traumas are more frequent in the elderly population, suffering from osteoporosis, and the most common pattern is joint depression.
In addition to cartilage damage of the articular surfaces, the most frequently associated lesions involve the meniscus (mostly, the lateral one), anterior cruciate ligament, medial collateral ligament, and the common peroneal nerve (external popliteal sciatic nerve). The conservative treatment of complex fractures is currently only minimally adopted, i.e., in some selected cases where intra-articular displacement of ≤ 2 mm, a metaphyseal-diaphyseal translation of < 1 cm, an angular deformity of < 10° in the coronal (varus-valgus) or sagittal plane, no open fracture, no associated compartment syndrome, no associated ligament injury requiring repair, no associated fractures of the ipsilateral tibia or fibula, open growth plates is present [2].
On the contrary, almost all these fractures require surgical treatment. It is estimated that today, in western countries, the relative surgical interventions are more than 10 per year per 100,000 inhabitants [3]. The goals to be achieved with surgical treatment are: to restore articular congruency and restore the tibial plateau width, maintain or regain axial and torsional alignment, recover metaphyseal-diaphyseal dissociation, restore joint stability, avoid infections and skin problems, and recover the joint and load without pain.

Appropriateness of classification

In the last 40 years several classifications have been proposed: Hohl (1967), Moore (1981), Schatzker (1979), Müller (1995) and Luo (2010). Among these, nowadays the most widely used one is undoubtedly that of the Canadian surgeon Joseph Schatzker [4].
The arrangement of the tibial plateau fracture characteristics and their schematic division into 6 easily and effectively detectable groups, each identified by a Roman number, probably represent the basis of the spread and success of this classification method. At the beginning, it was based on the two-dimensional representation of fractures, performed by radiographic examination. However, many authors have demonstrated over the years the limitations of this evaluation criterion, indicating that routine CT exam is a necessary tool for highlighting all the morphological characteristics of fractures, including the posterior aspect of the tibial plateau, thus identifying the appropriate surgical intervention.

In 2010, Luo presented the three-columns-classification, lateral, medial and posterior, based solely on the three-dimensional analysis of the tibial plateau [5]. Although not replacing Schatzker's classification, that of Luo's has been widely used and has been given credit for having recalled the attention of surgeons to the posteromedial fragment in type V and VI fractures, which are often overlooked or even ignored [6].
In 2018, Schatzker improved his classification by adding capital letters to the Roman number of the 6 groups, in order to define the involved quadrant, and lowercase letters, for briefly describing the course of the fracture line [7]. At present, we therefore believe that the updated Schatzker classification is the most appropriate method for describing the pattern and personality of the fracture, for guiding surgical treatment and for predicting outcomes.

Kirschner wires

Used often and successfully in the hand traumatology, k-wires have no longer been used in several years as the only "a minima" synthesis in the treatment of tibial plateau fractures. Currently, they may find use as temporary trans-articular augment, in association with internal plating, in those cases made complicated by multiple ligament injuries with instability [8].

Cannulated screws

Cannulated screws, despite not having the same resistance to the extraction as solid screws [9], i.e., they exhibit a lower joining effect, are however an excellent and irreplaceable device of synthesis in the treatment of all types of tibial plateau fractures. Used as a single device, they find appropriateness in uncomplicated type I fractures in patients with a good bone stock.
They are used in combined fixation, in association with plates or temporary external fixators, mainly in the treatment of complex V and VI type fractures. The most used alloy is the titanium-based one (wrought titanium-6aluminum-4vanadium extra low interstitial alloy) for lightness, strength and certified compatibility with MRI (ASTM standards). The diameter used is between 6.5 and 7.5 cm, on average, and with medium or short thread.
In the cases we treat, we use a washer only in the presence of insufficient bone stock (osteopenia/osteoporosis), in order to allow the best possible joining effect.

Arthroscopically-assisted reduction and internal fixation (ARIF)

Arthroscopy, whose support was tentatively proposed in the mid-1980s by Caspari and Jennings for the sole purpose of perfecting diagnosis, has now become an indispensable technique in the treatment of uncomplicated low-energy fractures of type I, II and III.

In recent years, several authors have shown that the clinical results of the arthroscopically-assisted reduction and internal fixation (ARIF) technique are significantly better than those of the open reduction internal fixation (ORIF) technique in treating low-energy fractures [10,11]. Arthroscopy allows performing a good joint wash, with the removal of osteochondral residues and blood clots, which may be arranged as fibrous adhesions. The direct and better viewing of bone damage, which allows a more precise reduction, the possibility of highlighting and acting on meniscal and chondral lesions, are the most important advantages of ARIF. In some cases, we have successfully applied meniscal sutures with all-inside technique, even in patients over 40 years [12]. The indications for a correct arthroscopic meniscal suture consist of recent lesions located in the red-red zone and in young subjects. The success of the suture in meniscal lesions, associated with tibial plateau fractures, even in subjects over the forth decade of life, is due to the particular damaging mechanism, which most often leads to the peripheral detachment of the meniscus in a well vascularized area. Therefore, the lesion healing occurs with the same proven repairing process that occurs when the meniscus is resutured, after surgical detachment, with ORIF interventions. The most frequently affected meniscus is the lateral one, which is usually less exposed to degenerative damage than the medial one in patients in this age group (Fig. 1), therefore the meniscal suture has reasonable possibilities of success even in patients over the fourth decade. The use of vertical suture techniques is superior to horizontally placed sutures, and permanent sutures are better than reabsorbable sutures [13]. The treatment of any ligamentous lesions detected during the examination is postponed until the fracture has healed.

Synthetic bone graft substitutes

In the surgical treatment of tibial plateau fractures one of the main and overriding goals is to restore the alignment of the articular surfaces and their congruence. During ORIF interventions, the presence of residual metaphyseal voids and gaps due to the displacement of fracture fragments is frequently found and, at times, must be treated by filling with bone graft. Moreover, during reduction maneuvers performed with bone tampers and similar instruments (i.e., inflatable tibioplasty ballon) in ARIF interventions, it is almost always necessary to fill the vacuum created by bone tamp itself, especially in type II and type III fractures, in order to maintain the reduction and support fixation. In the past, autologous bone has been used successfully which is still considered the gold-standard treatment for bone augmentation, osteoinduction and osteogenesis, but is associated with donor site complications and limited available quantity. Bone allografts have been used as second options for augmentation of tibial plateau fractures, but inferior healing, with respect to the use of autologous grafts, and the concern of potential disease transmission, have made the use of synthetic bone substitutes (SBS) increasingly popular.

At this time, the most commonly available SBS are calcium sulfate, calcium phosphate ceramics, calcium phosphate cements, bioactive glass, and polymethyl methacrylate bone cement [14].

SBS should have specific clinical use directions [15]. According to the literature, the most indicated bone substitutes in the tibial plateau fracture (and in open-wedge tibial osteotomy) are hydroxyapatite/β-tri-calcium phosphate ceramics and polymer-based substitutes. We believe that the most appropriate use of bone substitute biomaterials (BSBs) is in injectable form

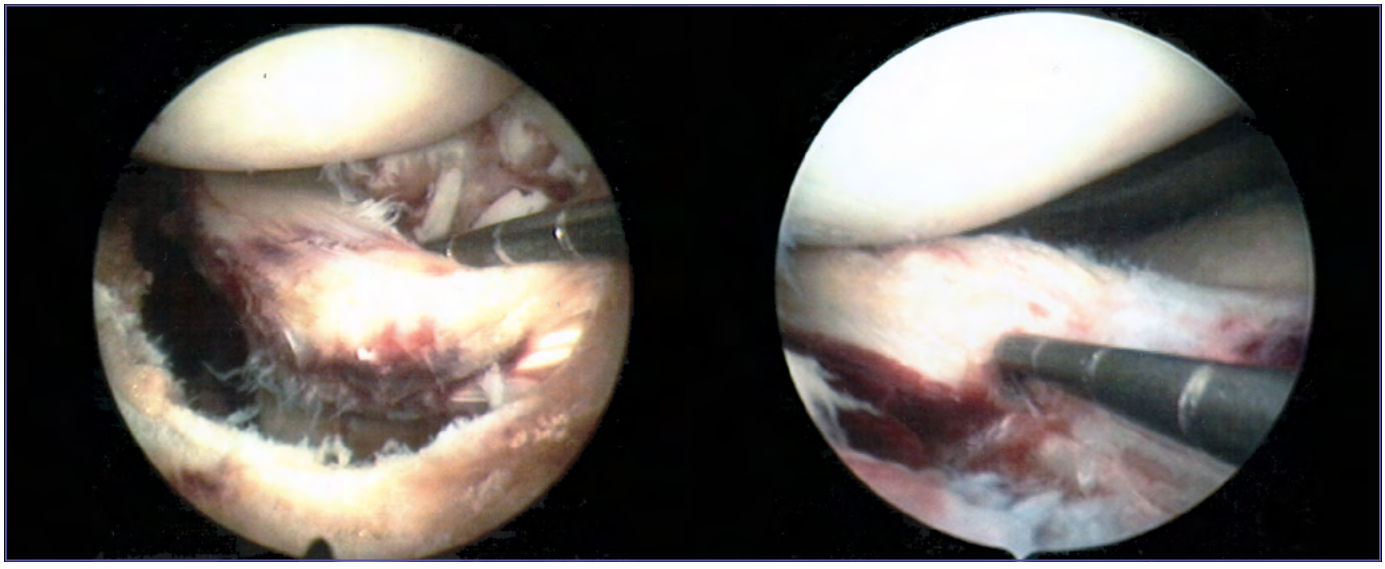

Figure 1. Lateral meniscus capsular separation is a frequent lesion in tibial plateau fractures. Arthroscopic suture, in this type of meniscal tear, can be successful even in subjects over the fourth decade of life.

for the treatment of type II and III fractures (Fig. 2). While the solid form is recommended, when needed, in the ORIF treatment of complex fractures type V and VI.

Plates

For many years, the use of two conventional support plates, implanted sideways and medially by means of a single median parapatellar incision, has been considered the gold standard treatment of bicondylar tibial fractures since 1979, according to Schatzker's indications [4]. This system offered rigid anatomical reduction, with a high percentage of soft tissue complications and nonunion, which, over the years, led to a different surgical approach (i.e., double incision technique) for the two plates positioning and to the use of different implant constructs, as fixed-angle locking plates (1995) and variable-angle locking plates (2011), for a biomechanically adequate osteosynthesis [16]. The so-called locking compression plates (LCP) were developed by the AO in 2003 and can be biomechanically compared to an internal fixator. They present a combination of locking screw with conventional screws with an extraperiosteal location of plate.

Figure 2. Bone void filler of metaphyseal area after arthroscopic reduction of plateau fracture in pure Schatzker III (zero column of Luo classification). No further fixation was performed in this fracture.

In the variable-angle locking plates, the screw can be locked with a certain clearance within a cone with an angle in the range of 1° to 15° [17].

The availability of this modern type of more biological and biomechanically adequate osteosynthesis has driven some authors towards the use of a single plate to treat the bicondylar fractures [18]. No significant difference between unilateral locking plate and dual plating in treatment of complex bicondylar tibial plateau fractures has been observed. However, this is likely to happen in very selected cases, when the medial tibial plateau fracture is a non-displaced fracture.

We believe that the most appropriate case for the use of single lateral plating is the unicondylar fractures, lateral (type I-II) and medial (type V).

The three-column concept modified the approach to the fixation of posteromedial fragments. In the cases of coronal posteromedial fragment displacement a posterior approach may sometimes be necessary (i.e., as Lobenhoffer approach) to place an angular stable dorsal anti-glide plate to obtain optimal fixation.

In recent years, many authors have shown that, in type V and VI fractures, the best approach seems to be the use of the double incision technique (medial and antero-lateral) for dual plating (Fig. 3). Therefore, it appears to be a distinctive decrease in deep infection rates, compared to procedures with single incision [19].

Temporary external fixators

Soft tissue status guides the choice of the timing and modalities of the fixation. Surgeons must be patient in treating high-energy proximal tibial fractures and embark on operative reduction and internal fixation only when the soft tissue has recovered enough for tolerating an additional insult [20]. Fine-wire external fixation, using circular or hybrid frames, allows knee spanning and ligamentotaxis, improves fracture fragment gross alignment, minimizes further damage to articular surfaces and permits early damage control, namely, soft tissue assessment and wound care.

In addition to severe soft tissue trauma, temporary external fixation (TEF) finds appropriate use in axially unstable tibial plateau compound fractures as Schatzker type V an VI. In these cases, TEF also allows the restoration of metaphyseal-diaphyseal dissociation (Fig. 4) and may be associated with minimal open reduction and percutaneous screw fixation.

External fixation can also be used as final ostheosynthesis, with some advantages, such as good stabilization and protection of soft tissue healing; moreover, it allows early range of motion.

Among the disadvantages, inadequate reduction, an elevation of pin track risk, and difficult acceptance and compliance by the patients should be noted.

In a recent review, McNamara has performed a comparison with open standard reduction techniques, by evaluating four

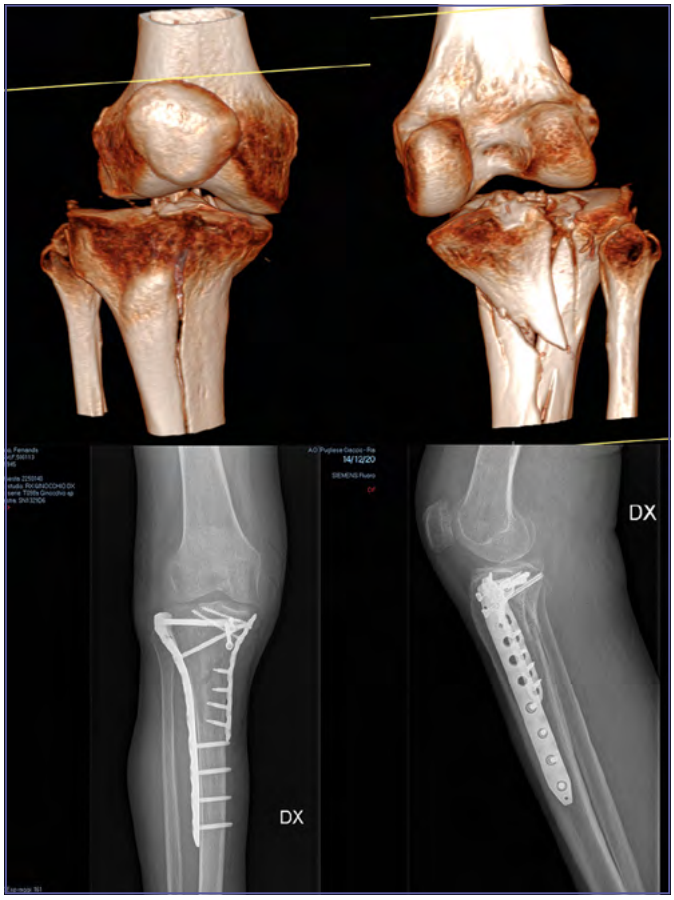

Figure 3. A 73-year-old woman with transverse subcondylar tibial plateau fracture and disrupted continuity of the metaphysis (Schatzker type VI) treated with a double incision, medial buttress plate, lateral variable-angle locking plate plus screws.

randomized and two quasi-randomized trials. The analysis showed that there is insufficient evidence to ascertain the best surgical methods of fixation [21].

Primary total knee arthroplasty

Due to the patient's age and to the complexity of fracture, elderly patients with type V and type VI have high risk of needing a total knee arthroplasty (TKA) after operatively treated tibial plateau fracture. In his review, Wasserstein pointed out that 7.3% of patients with a tibial plateau fracture will develop ostheoarthritis needing TKA in a 10-year follow-up after injury, *versus* 1.8% of patients without a fracture [22].
Moreover, TKA performed as treatment of post-traumatic arthritis after ORIF is often more technically difficult, compared with TKA performed on patients with primary arthritis and clinical outcome. Also, implant survival after TKA in first group is lower than in

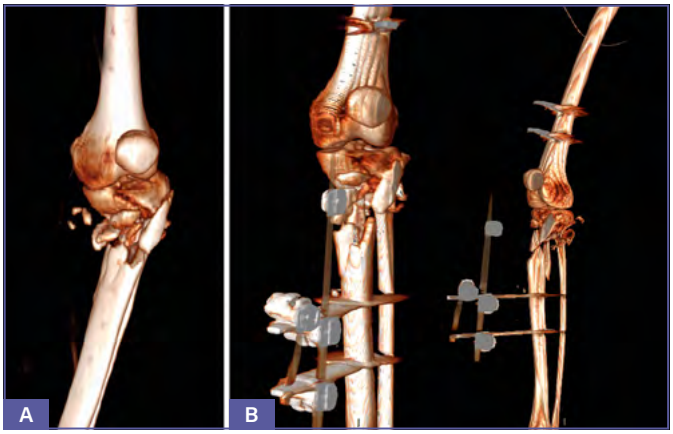

Figure 4. Temporary external fixator implanted in Z configuration (two lateral pins in femur and two antero-medial pins in tibia) in Schatzker VI with restoration of metaphyseal-diaphyseal dissociation.

second group. For this reason, some authors have suggested that in certain geriatric patients, with complex tibial plateau fracture, poor bone quality and severe pre-existing OA (Fig. 5), TKA could be the primary procedure to treat this proximal tibial fracture [23]. The advantage is quick post-operative mobilization with the possibility of a full-weight bearing. Therefore, these patients maintain the mobility they had prior to the operation so that primary TKA, for complex tibial plateau fractures in orthogeriatric patient, could be an interesting alternative to ORIF [23].

Conclusions

The treatment of complex tibial plateau fractures is a very important topic and there is still a high degree of controversy about different aspects of the surgical treatment.
Surgeons must understand the fracture pattern and respect for soft tissues is necessary.
In general terms and in uncomplicated fractures, the most appropriate treatment for partial articular fractures (Schatzker I-III) is single plating and/or interfragmentary screws. In these three types of fractures, arthroscopy is an essential technique for improving the accuracy of treatment along with use of synthetic bone graft substitutes.
In Schatzker IV, accurate evaluation of posterior medial component is necessarily followed by an adequate approach in order to have direct reduction and optimal fixation with buttress plate.
External fixation, ORIF or TKA are the different appropriate procedures in complex bicondylar tibial plateau fractures (Schatzker V and VI), depending on the state of soft tissues, pattern of fracture, age, comorbidities, bone stock, patient compliance and severe pre-existing OA.

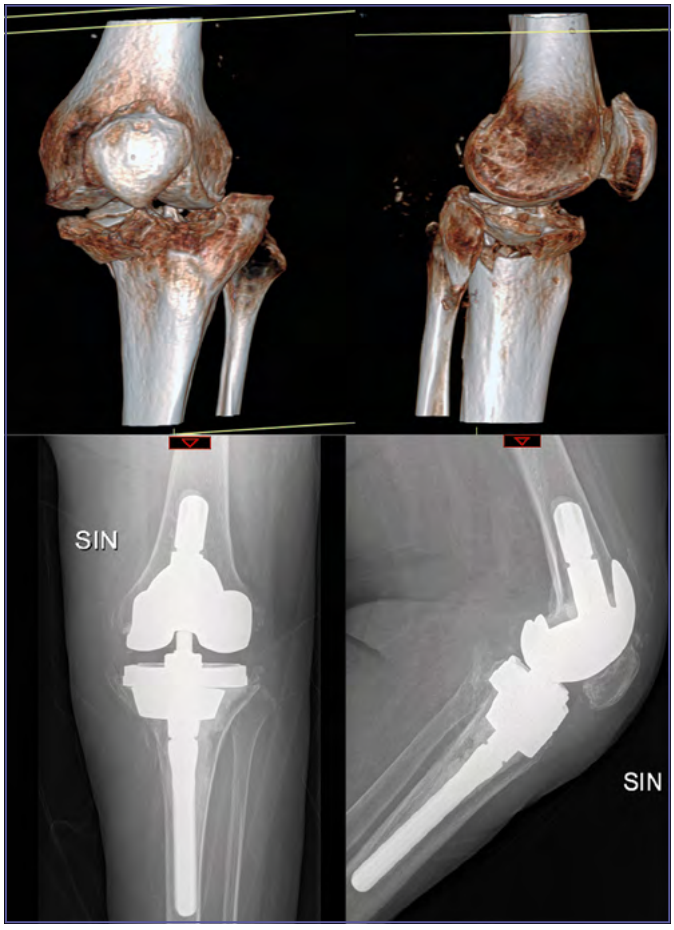

Figure 5. Semi-constrained arthroplasty performed in 76-year-old-woman with bicondylar fracture (type V) in severe pre-existing osteoarthritis and poor bone stock.

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