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Comparative Evaluationamongthe Conventional Open Surgical Techniques and the MinimallyInvasiveTechniques for the Treatment of Tibial Plateau Fractures - A Review of Literature

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Abstract:*Tibial plateau fractures (TFP) are serious injuries of the knee and difficult to treat.In the past decades, many kinds of fixation methods have been proposed in the literature. From non-operative management to current staged and combined management with provisional external fixators, before conventional angular stable platingshave been suggested for complex TPF. The conventional techniques have been widely accepted, but many patients developed complications and unsatisfactory outcomes. Restricted internal approaches likeMinimally invasive plate osteosynthesis(MIPO), Less Invasive Stabilization System (LISS) and further less invasive techniqueslike fine-wire apparatuses, arthroscopically assisted fixation, tibialtuberoplasty and tibial nailing for selected cases have been developed.Most authors agree that functional outcomes of complex TPF depend mainly on the quality of anatomical and stable reduction of the intra-articular and posterior fragments while the type of fracture may be deemed as an independent predictor. Minimally invasive techniques have been proven to provide fewer complications, better functional outcomes, and early weight-bearing than the conventional open surgical techniques.*

Keywords:*Tibial plateau fracture;conventional surgical techniques;minimally invasive techniques*

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I. Introduction

Tibial plateau fractures (TFP) occur due to a combined axial loading force and a coronal plane (varus/valgus) moment. They consist of a broad range of injuries presenting various challenges to the orthopedic surgeon.[1]TPF account for approximately 1% of all fractures with a yearly incidence of 10.3 per 100,000 people.[2,3]The Schatzker classification remains the widely accepted traditional classification system on which treatment of specific injury patterns is based.[4]The prognosis of such fractures depends mainly on the management of each specific pattern, and many management strategies have been described in the literature but with limited agreement. All sorts of fixation methods have been suggested in the literature.From non-operative management, to current staged and combined management with provisional external fixators, before conventional angular stable plating have been suggested for complex TPF. The conventional techniques have been widely accepted, but many patients developed complications and unsatisfactory outcomes. Minimally invasive approaches like fine-wire apparatuses, arthroscopically assisted fixation, tibial tuberoplasty and tibial nailing for selected cases have been developed.[4-12]

II. Initial management

TPF presenting with vascular compromise along with fracture-dislocations should be urgently managed. Compartment syndrome is an emergency that requires a timely four-compartment fasciotomy irrespective of the planned definitive management, and compartment syndrome should be evaluated at every stage during the management. Open fractures including gross contamination require urgent management as well and abidance by locally approved guidelines. Early vascular and orthoplastic input should be searched for were indicated by the type of injury and the amount of soft tissue compromise.[3] Although low-energy injuries can be treated early using a single procedure, injuries with a substantial compromise to the soft tissue envelope in addition to high-energy injuries in an otherwise physiologically compromised host may require staged damage control principles.[13]

Staged management consists of the use of provisional management techniques for high-energy injuries, besides delaying definitive fracture surgery until the risk of complications of soft tissue is reduced or the patient's general wellbeing has improved.[14]Initial damage in severe cases can be managed using splints, casts, traction, and braces, however, the idealprovisional treatment is spanning external fixation.[7,15,16]Egol showed that staged management with standardized protocol brings abouta low incidence of infections (5%) and relatively low complication rates, with a possible drawback of enduring knee stiffness.[17] Spanning external fixators decrease fracture fragments throughligamentotaxis, as well as relieve the pain and enable a stable environment for soft tissue healing, besides early mobilization.[7]

III. Definitive treatments

Conventional ORIF

In the 70s, prior to the open surgical techniques, Rasmussen showed satisfactory outcomes with conservative treatment but acknowledged the increased incidence of posttraumatic osteoarthritis and malunions, though non-surgical management remained preferable till many years later concerning complex injuries.[5,18-20]The most common definitive management for displaced TPF has been open reduction and internal fixation(ORIF) with the repair of the articular surface to as close aspossible to the normal anatomy and to maintain the reduction whilst early knee joint motionis resumed.[4,21-25]Since 1979, Schatzkeret al. initiallyrecommendedconventional dual plating with buttress plates across a single midline incision for managing bicondylar TPF which can help to attainstable anatomic reduction for the articular partsand has been viewed as the gold standard of treatment.[4,26-28]The surgical approach should be chosen based on the pattern of fracture, the conditionsof the patient, and the soft tissue cover.Over the years, various approaches have been described for managingTPF. Double incision technique for dual plating was shown to bringa lower rate of wound complication,infection and adverse effects compared to the previously reported complications with single-incision procedures.[29-32] Moreover, Qui et al. describedthe posterior reversed L-shaped approach (PRLA) and showed good outcomesin posterior column fractures with bevery goodvisualization of the medial and posterior column of the tibial plateau.[33]

Despite that, the conventional open surgical technique for TPF using plates and screws allows direct visualization of fracture, reduction, and fixation, it does not permit for the concomitant diagnosis and treatment of other possible injuries, like injuries of meniscus or ligaments. Furthermore, it brings about extensive devascularization of the bone and skin, risks wound breakdown, increases risks of infection, and functional rehabilitation complications (like pain and stiffness) with delayed recovery of weight-bearing.[23,34]The proximal part of tibia gets its vascular supply from an intramedullary network for the inner two-thirds of the cortex and a periosteal network for the outer one-third of the cortical bone. TFP frequently compromise the vascular supply from the intramedullary network but partly spare the periosteal network.[35,36]Many investigators note that conventional plate fixation techniques cause further damage to the vascular supply of bone.[37-39]However, there are ongoing researchesabout the development and improvement of conventional ORIF. In 2015,Huang et al. propose the usageof 3D printing and digital technology toimprove surgical planning of ORIF and deduced that this technique can enhance the outcomesof internal fixation.[40]

IV. Minimally invasive techniques

External fixators

External fixation by means of circular or hybrid frames is being more approved since it permits for early weight-bearing without restrictions associated with the state of the skin. It is considered the ideal treatment technique in cases where massive dissection and internal fixation are contraindicated because of soft tissue injuries, lack of bone filing, and severe comminution.[41] Ilizarov apparatus and Taylor frame have been successfully used in the definitive treatment of complex TPF but there is a risk of pin tract or deep infection and inadequate reduction.[42] Many authors reported good outcomes using external fixators in combination with minimally open reduction and percutaneous screw fixation, femoral frame extension, or even bone grafting, through a tiny incision in severe metaphyseal osseous gap and comminution cases.[43-46]

The complication rates of infection due to external fixation vary in the literature. Ali et al. reported a 20% pin tract infection and 1 case of deep infection in 25 patients with open complex TPF managed with a circular fixator.[47] On the other hand, Hutson et al. did a meta-analysis of 568 patients and reported a 10% pin tract infection rate.[48] Furthermore, Subasi et al. reported satisfactory outcomes in 15 open comminuted TPF managed with a circular fixator but in the coronal plane, they observed inadequate anatomical reduction and loss of reduction in the comminuted posterior column fractures.[49] Moreover, external fixators must be retained while waiting for adequate healing, which makes the patient's approval and compliance problematic.

Many studies compared internal fixation methods to external hybrid or circular frames in relation to different outcome aspects with no clear results. In theory, pertaining to soft tissue envelope, a circular external fixator compared to double plating, can be associated with lower infection rates, less blood loss during surgery,

shorter hospital stay and less unplanned surgical revision.[50] Mahadeva et al. compared ORIF and Hybrid fixation in Schatzker type VI fractures, but could not demonstrate that hybrid fixation is better since partial deformities remain high and poor functional outcomes in both groups.[51] However, studies could not show significant differences in functional outcomes among external fixators, conventional and angular stable plating.[50,52,53]Moreover, Yu et al. showed that the external fixation group is more associated with knee joint instability, malunions and post-traumatic arthritis whereas in the plating group, heterotopic ossification, valgus malalignment, and higher local irritation risk are more prevalent. But there were no differences in mean union time, range of motion and rate of revision surgery. Good to excellent results were also reported in 90% of the high-energy fracture series, regardless of the evaluation system used.[54]

Limited internal fixation

Both internal and external fixation of high-energy TPF has been relatedtoa high risk of complicationssuch as infection, necrosis, and non-union.Extraperiosteal dissection compared to subperiosteal dissection impedes healing more, and transection of muscle significantly delays the healing. Many researchers were persuaded to investigate minimally invasiveor percutaneous techniques of fixationlaying emphasis on limiting surgical damage to the superimposing soft tissues making plate osteosynthesis a feasible option in high-energy TPF with severe soft-tissue injuries.[4,37-39,55,56]High-energy fractures managed using minimally invasive techniques are less reported. Some studies tried to modify the concept over the effect of single midline incision on soft-tissue compromise concerning complex TPF and dual platingand found a much lower incidence of nonunion and infection.[57,58]Apart from improvements based on the surgical approaches, bio-friendly angular-stable plates like MIPO technique, Less InvasiveStabilization System (LISS), locking compression plates (LCPs),Arthroscopically-assisted Reduction and Internal Fixation (ARIF) have been introduced and used in numerous combinations with conventional plates or screws. They allowminimally invasive fixation and capable of providingample stability even in highly comminuted or osteoporotic bones.[59]

Minimally invasive plate osteosynthesis(MIPO) techniques

Minimally invasive plate osteosynthesis (MIPO) enables indirect fracture reduction without exposure of the fracture site and percutaneous submuscularintroduction of the plate with separate proximal and distal incisions. This enhances the healing rate due todiminishingdissection of soft tissues,devitalization of fracture fragments,and preserving blood supply at the fracture site.[60-62]There isa lower incidence of soft-tissue problems, postoperative pain and thusenables early rehabilitation, which enhances articular cartilage healing and can achieve better functional outcomesthanusing the conventional ORIF.[63-67]Furthermore, it is cosmetically more acceptable as a result of less scar formation.[68]

Less Invasive Stabilization System (LISS)

The tibial Less Invasive Stabilization System,LISS system was invented to mingle the favorablefeatures of minimally invasive osteosynthesis along with the benefit of a fixed-angle implant systemthat efficientlytacklesmany of the issuesrelatedto high-energy TPF, including malalignment during fracture healing without the need for additional medial fixation. The LISS system utilizes a pre-contoured plate that is suitable for a broad range of tibial shapes and sizes. There is an indentation on the LISS plate that allows the clamp to make a firm reduction of the plate with the bone. This is important with the LISS plate because when implanted, the screws will not pull the plate tightly against the proximal tibia compared with the conventional systems. Using the LISS system, Stannard et al. reported that malunion, malalignment,or loss of articular reduction wereunnoticeable at the time of osteosynthesis and during the postoperative period.[65]Egol et al. reported a 95% union in 38 patients with complex TPF.[17]Ikuta et al. reported 25% good and 75% excellent functional outcomes and no complications for their 12 Schatzker V and VI fractures.[69]

However, Gosling et al. reported 23.5% immediate postoperative malreduction and 9% loss of reduction after LISS fixation in 68 patients who sustainedAO type 41-C fractures. They observed that reduction technique using LISS for achieving exact alignment is challenging.[70]Besides, Barei et al. recognized a posteromedial fragment in one-third of the bicondylar fractures and pointed out possible consequences when attempting a single lateral fixation using angular-stable implants.[71]Likewise, Weaver et al. reported that intheir single-plate fixation group, there is a substantial loss of reduction and sagging when a medial coronal fracture line exists.[72]Nevertheless, the LISS systemseems to diminish the infection risk, even though one plate is useddespite severe open fractures. The minimally invasive technique comprisingof the absence of soft-tissue and periosteal stripping are all important forthe effective use of this implant in open fractures.

Arthroscopically-assisted Reduction and Internal Fixation (ARIF)

Arthroscopically-assisted Reduction and Internal Fixation (ARIF)uses arthroscopy and percutaneous fixation. ARIF was originally described by Caspari and Jennings in the 1980s.[73,74]It is broadlyrecognized as a reliable method for managing Schatzker type I to IV fractures. It alsoallows direct diagnosis and treatment of

injured meniscus and ligaments as well asextraction of loose fragments.However, the treatment of Schatzker type V and VI fractures using ARIF is still debatable.[11,75-77]

Herbort et al. evaluated theoutcome offractures corresponding to Schatzker type I to IV managed by ARIF.They contraindicated thetreatment of complex TPF by ARIF due to the high risk of compartment syndrome caused by fluid extravasation, althoughit is veryrarely reported.[76,78]Nonetheless, there are some works in the literature that are in favor of ARIFas a safe method with good to excellent outcomes when done by experienced surgeons.[79,80]Chen et al. found this ARIF as a safe optionfor bicondylar fractures and with fewer complications. ARIF has a lower incidence of infection compared to ORIF but further investigations are required.[81]

ARIF is best indicated for the pure split, pure depression, and split-depression fractures of the lateral tibial plateau for which arthroscopy is most beneficial when stable percutaneous fixation is consistent with immediate mobilization.In complex TPF, the arthroscopy performed by askilled surgeon can reduce the surgical trauma, given that stable fixation is consistent with early mobilization.In 2018, Li et al. used arthroscopycombined with the MIPO technique for the treatment of Schatzker type IV TPFwhich at the same time, can treat other injuries like meniscal damage among others, with fewer complications, and earlier recovery of joint function.[11,82]

Tibial nailing

Tibial nailing is another good minimally invasive option in the treatment of particular fractures of osteoporotic bones. Garnavos et al. described an ideal alternative in the treatment of complex intra-articular TPF without significant impaction. They also showed good outcomes in patients with low requirements and permitted early mobilization of the knee.[10]These findings were further supported by the biomechanical investigations of Högel et al. and Lasanianos et al. that showsimilarities to fixation by a single lateral locking plate and similar or stiffer implant-bone construct.[83,84]Afterward,Garnavos et al. introduced aretropatellar approach which helps withvisualization issues during surgery and maintenance of reduction due tothe previously described free-hanging position.[85,86] Nevertheless,this method should be performed by highly experienced surgeons and in selected cases and morestudiesare required to compareretropatellar nailing with compression bolts to conventional treatments.

Tibial tuberoplasty

Vendeuvre et al. described a relatively new minimally invasive technique baptized 'tibial tuberoplasty' using balloon and percutaneous screws with polymethylmethacrylate (PMMA) cement filling. It is mainly suitable for the reduction and stabilization of Schatzker type II and III TPF. Arthroscopy was important in the visualizationof the concomitant lesions, leakage of cement,and to verify the reduction of fracture.[12]

Different from the technique using bone tamp, an avascular window allows the anterior point of entry below the fracture site, which preserves the vascular supply to the periosteum promoting bone union, reduces risks of infection,and cosmetically more appealing.[35]Furthermore, the balloon permitsentry to the posterior compressions while avoiding the vascular and neurological risks with a conventional technique. Also, there is no muscular damagethatlessens postoperative pain and eases rehabilitation.[12]

In a prospective study, Ollivier et al. treated 20 patients with Schatzker type II and III fractures usingtuberoplasty with calcium phosphate cement filling. They found that balloon-guided inflation tibial tuberoplasty with a resorbable bone substitute is reliable, and ensures a high rate of anatomic reduction and good functional outcomes in depressed lateral TPF.[87]In a recent randomized controlled trial, Doria et al. evaluated tibialtuberoplasty against conventional reduction technique in 30 patients with Schatzker type II and III fractures. They conclude thattuberoplasty allows anatomical fracture reduction in a stealthy and gradual manner and mechanical stability whichenables early rehabilitation and weight-bearing.[88]

V. Conclusions

TPF are serious trauma injuries, frequentlyassociated with softtissue related complications. Staged management should be prioritized in severe cases, which include early damage control, proper management of soft-tissue injury along a well-planned surgical treatment based on the specific type of fracture is recommended. Minimally invasive techniques are recommended in selected cases partial articular fractures. Arthroscopy can help in fracture reduction and allow the repair of meniscal or ligament injuries. ARIF and tibial tuberoplasty are suitable options for Schatzker type I to III TPF. Tibial nailing is shown as appropriate in the treatment of fractures of osteoporotic bones. Complete articular fractures are better treated by ORIF or by external fixators and minimally invasive techniques like MIPO and LISS. Most authors agree that functional outcomes of complex TPF depend mainly on the quality of anatomical and stable reduction of the intra-articular and posterior fragments while the type of fracture may be deemed as an independent predictor.

Minimally invasive techniques have been proven to provide fewer complications, better functional outcomes and early weight-bearing than the conventional open surgical techniques. Nevertheless, a high level of surgical skill and experience is required regardless of the techniques used. Although further studies are expected, the uniqueness of each fracture pattern, the severity of the soft tissue injuries, the conditions of the patient, the wide choice of fixation methods and a lack of evidence regarding higher-level randomized trials altogether make it extremely challenging for the consensus of gold standard treatments to be reached.

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