Early Revision Surgery for Tibial Plateau Non-union and Mal-union

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Abstract *Background:* Although relatively rare, non-unions and mal-unions of tibial plateau fractures present significant challenges for the orthopedic surgeon. With careful pre-operative planning, tibial plateau mal-union or non-union revision surgery with intra-articular and varus opening osteotomies can provide good functional results when performed early (within 1 year) after primary surgical procedure. *Questions/Purposes:* We present our treatment algorithm for approaching and treating non-union or mal-union of tibial plateau fractures. Our aim is to give surgeons treating these difficult injuries an overview of the pertinent literature as well as describe the challenges and pitfalls we have experienced when treating non-union or mal-union of tibial plateau fractures. *Methods:* Using two case examples from our institution, one for mal-union and one for mal-reduction, we describe our treatment algorithm and surgical technique for managing these difficult

injuries. We also provide a brief literature review outlining relevant studies and summarizing outcomes for similar injuries. A systematic literature review was conducted with the aim of determining the methods and outcomes commonly reported in the literature regarding revision surgery following tibial plateau non-union or mal-union. Due to the nature of revision surgery, there are no long-term randomized trials dealing with outcomes, but rather several smaller case series exist from which larger conclusions have to be drawn. *Results:* To date, we have successfully treated approximately 35 patients with this technique, and clinical follow-up continues to show good functional outcomes with reduced pain and little radiographic evidence of arthritic changes. Restoring long leg alignment, anatomic reduction of the articular surface, and achieving stable internal fixation are paramount in achieving the best long-term outcome. Due to the shallow soft tissue envelope around the proximal tibia, and the tendency for these fractures to fall into progressive valgus collapse, these problems can seem intimidating and complex. However, with well-planned surgery and meticulous surgical technique, reliable healing can be achieved. *Conclusion:* By outlining our method, we hope to provide other surgeons with an algorithm to guide clinical and operative decision making. These difficult injuries can be daunting to treat, but if performed before the onset of severe degenerative arthritis, early revision surgery, as we describe, can be a viable alternative to total knee arthroplasty, particularly in younger, more active patients.

Level of Evidence: Level IV: Surgical Technique

Research performed at Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands.

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Introduction

Tibial plateau fractures are relatively rare, comprising a reported 0.8% of all fractures [3]. These fractures occur in a bimodal distribution. Younger patients' fractures are due to higher energy mechanisms, while those of older osteoporotic patients are often due to low energy mechanisms. When treating these fractures, it is imperative to restore a

congruent articular surface as well as overall long leg alignment to reduce the incidence of post-traumatic arthritis. Even with anatomic reduction, the incidence of post-traumatic arthritis is estimated to be 44% [7, 10]. Treatment strategies have evolved with better pre-operative diagnostics (2D and 3D CT), new surgical approaches, improved fixation devices, and staged reconstruction for high-energy fractures. Fortunately, non-union is relatively uncommon because the proximal tibia enjoys a robust blood supply and a large metaphyseal cross-sectional area [1]. This has been well reported in the literature, with Sarmiento reporting a non-union rate of only 2.7% with 118 proximal tibia fractures treated non-operatively with functional bracing [2, 8]. Additionally, in a very large series of 988 intra-articular tibial plateau fractures, Moore et al. reported only one case (0.1%) of metaphyseal non-union [9].

The incidence of mal-reduction or mal-union of tibial plateau fractures is likely to be much more common, although this is not well described in the literature.

A mal-reduced or mal-united tibial plateau presents a significant challenge to the orthopedic surgeon. The goals for reoperation are clear: anatomic articular reduction, restoration of long leg alignment, bone healing, and restoration of full function. Surgical issues to be dealt with are the often compromised and thin soft tissue envelope, previous scars, failed hardware, poor bone stock, and stiffness of the knee. Especially for a mal-reduction (also called a nascent mal-union) or a true mal-union, the decision whether or not to revise can be intimidating. First of all, there is not a clear definition of what should be considered a mal-union. Krettek et al. described a classification of tibia plateau mal-unions based on location (medial, lateral, combined, intra- or extra-articular or both, condylar or intra-condylar), geometry, severity, and progression [6]. As each fracture resulting in mal-reduction or mal-union is different, treatment necessitates an individually based approach.

The purpose of this paper is to describe treatment strategies and early revision surgery used to treat mal-reduced

Fig. 1. Axial (a), sagittal CT (b, c), and long alignment X-ray (d) revealing intra-articular tibial plateau mal-reduction with valgus long leg alignment.

tibia plateau fractures and mal-unions of the tibial plateau as illustrated with case examples. In our experience, the early treatment of these problems leads to decreased pain and better functional outcomes.

Patients and Methods

Pre-operative Evaluation

The patient's history should be focused on complaints about stability, pain, infection, and stiffness. The patient should be asked about pre-injury activity levels and expectations. Evaluation of range of motion, gait, and stability and a neurovascular status should be carefully documented. Soft tissues and previous scars should be scrutinized. Previous operative reports should be checked for details on exposure, type of hardware used, intra-operative problems, bone quality and defects, and the status of the cartilage, cruciate ligament, and menisci.

Radiographs should include standing full-length films, along with AP and lateral of the knee. A 2D and 3D CT is needed to judge the intra-articular surface. It can be helpful to mirror image the healthy contralateral side to measure loss of height and differences in width of the plateau. If radiographs are unclear, union can often be more easily determined by CT, rather than plain films. Some authors also recommend an MRI to further evaluate soft tissue and meniscal injury [11].

When confronted with non-unions and/or infection, the indication for surgical intervention is often clear. Obviously, if no surgical intervention is done in these patients, the problem will most likely remain or get worse. However, for mal-reductions and mal-unions, there are no clear guidelines whether to revise or not. The most common complaints in these situations are pain, valgus deformity, and/or giving way (pseudo-laxity). The range of motion is often quite well preserved. The decision whether to operate or not is made on an individual basis. Referral to a surgeon with a specific interest and/or expertise is warranted.

Case Example 1: Mal-union

A 50-year-old female sustained a left posterolateral intra-articular tibial plateau fracture (Schatzker 2). Patient underwent lateral plate fixation of the tibial plateau at an outside institution after soft tissues were amenable. Post-operatively, the patient experienced continued pain and a valgus deformity of the knee. She was referred to our institution for a second opinion. CT demonstrated a posterolateral intra-articular tibial plateau mal-reduction with posterolateral fragment depression and possibly intra-articular hardware. Standing films clearly showed the valgus deformity of the left knee (Fig. 1).

Approximately 6 months status post initial plate fixation, the patient underwent revision surgery. The patient was placed supine on a radiolucent table. The prior anterolateral surgical incision was utilized. A peroneal nerve decompression was performed to prevent nerve injury. A universal femoral distractor was placed to obtain optimal visualization of the joint surface. The joint surface appeared quite good without significant macroscopic damage. Five osteotomies were completed. The first was a mid-shaft fibula osteotomy to allow for varization in

combination with the anticipated proximal tibia osteotomy. The second osteotomy was a Gerdy's osteotomy for increased visualization of the plateau. The third was a fibular head osteotomy to allow even further visualization of the posterolateral quadrant. Fourth, a proximal tibia osteotomy was done for varization of the valgus deformity. Lastly, an intra-articular osteotomy was done to correct the mal-reduced lateral plateau (Fig. 2).

After completion of the intra-articular osteotomy and extra-articular osteotomy with placement of tri-cortical auto graft, internal fixation was implemented as was fixation of osteotomy sites. No allograft fillers or bone morphogenetic proteins (BMPs) were used in conjunction with the tri-cortical autograft. At the end of the case, restoration of the mechanical axis had been achieved (Fig. 3).

Post-operative films of the left knee revealed restoration of the joint surface with anatomic reduction and excellent fixation of the tibial plateau (Fig. 4). As a complication, the patient had a post-operative peroneal nerve palsy that resolved within weeks. The peroneal nerve had been identified and protected but in retrospect, we may have had too much distraction by using the femoral distractor. She also needed revision for a proximal fibula non-union with tension band and bone grafting.

Post-operative weight-bearing status consisted of toe-touch weight bearing for 6 weeks then slowly advanced to full weight bearing by 3 months. Patient received low molecular weight heparin for deep-vein thrombosis prophylaxis while in the hospital and continued for 6 weeks, which is the

Fig. 2. Intra-operative photos of the lateral tibial plateau. Image A demonstrates the intra-articular osteotomy. Image B demonstrates extra-articular wedge osteotomy to restore long leg alignment. Femoral distractor is utilized to regain length and distract through the joint.

Fig. 3. **a** Varus producing lateral opening wedge osteotomy. **b** Rafting screws used to provide provisional support for articular reduction. **c, d** AP and lateral images with tri-cortical autograft and final fixation in place. **e** Intra-operative photo showing lateral plate fixation for both intra- and extra-articular osteotomies.

same protocol used in acute fractures. A three-sided long leg splint was applied post-operatively and remained for 2 days to allow for soft tissue rest. Gentle active-assisted range of motion was initiated on post-operative day three. No continuous passive motion machine (CPM) was used. She was most recently seen at 2 years after surgery and had regained full motion and was unlimited in her activities.

Case Example 2: Mal-reduction

A healthy 38-year-old male sustained a bicondylar Schatzker 5 fracture of his right plateau. Both posterior condyles were involved with comminution. He underwent open reduction and internal fixation at an outside hospital with two screws and washers. The reduction was non-anatomic, and the patient was referred for revision (Figs. 5 and 6).

During revision, the previous posterior approach was used, and the hardware was removed. Based on the posterior

cortex, the extra-articular aspect of the plateau could be perfectly reduced. A plate and screws were used for fixation. However, a $2 \times 1 \times 1$ -cm fragment with articular surface (but without cortex) could not be fitted exactly from this posterior approach. Again, the articular surface appeared quite good without significant macroscopic damage. It was decided to store the fragment in -20°C and to obtain a CT after closure to see where the residual defect resided; this allowed optimal planning of the second revision to replace the stored fragment. Once the posterior wound had healed and the CT was obtained, the patient returned to the operating room for the final procedure. The CT clearly outlined the defect in which the stored fragment would have to be placed (Fig. 7).

We felt revision was not feasible from a posterior approach. Using an anterolateral approach, an intra-articular osteotomy of the lateral plateau was made to provide easy access to the residual posterolateral defect. The anterolateral osteotomy was made under direct visualization through an

5 osteotomies

Fibula

1. Shaft
2. Head

Tibia

3. Gerdy's
4. Extra-articular
5. Intra-articular

Fig. 4. Post-operative films left knee reveals restoration of the joint surface with anatomic reduction and excellent fixation of the tibial plateau. Note: five osteotomies used to obtain congruent joint surface and anatomic long leg alignment along the (1) fibula shaft, (2) fibula head, (3) Gerdy's tubercle, (4) extra-articular tibial aspect, (5) intra-articular tibial aspect.

area where no weight-bearing cartilage was present. Using a thin osteotome, the osteotomy was completed, and the anterolateral plateau was hinged open like a book. The missing fragment was recovered from the -20°C freezer, cultured, and replaced in its perfect position. A lateral plate was used to buttress the reconstruction and osteotomy. The ACL/tibial

eminence fragment was not specifically addressed. The laxity exam was fairly benign and the fragment was left in place. No allograft fillers or bone morphogenetic proteins (BMPs) were used in this case.

Post-operative weight-bearing status consisted of toe-touch weight bearing for 6 weeks then slowly advanced to

Fig. 5. a, b, c Lateral X-ray, sagittal, coronal, and (d) axial CT left knee injury images revealing a tibial plateau fracture involving posterior medial and lateral plateau fractures.

Fig. 6. a, b AP, lateral radiographs, coronal, sagittal, and c, d, e axial CT images of left knee mal-reduction status post screw and washer fixation performed at an outside facility.

full weight bearing by 3 months. Patient received low molecular weight heparin for deep-vein thrombosis prophylaxis while in the hospital and continued for 6 weeks, which is the same protocol used in acute fractures. A three-sided long leg splint was applied post-operatively and remained for 2 days to allow for soft tissue rest. Gentle active-assisted range of motion was initiated on post-operative day three. No continuous passive motion machine (CPM) was used. At 3 months, the fracture had healed. Two years after surgery, the patient had returned to all activities; he regained full range of motion with normal alignment and had no pain and no radiographic evidence of arthritic changes (Fig. 8).

Discussion

Anatomic reduction of the joint surface, restoration of the mechanical axis, and stable internal fixation are the primary goals in treating fractures of the tibial plateau. However, due to mal-reduction, mal-union, non-union, or infection, these goals are not always met. As described in the Schatzker classification, lateral-sided comminution and joint depression are more common than medial-sided injuries [5, 12]. Additionally, when the medial tibial plateau is involved, the posteromedial fragment is usually an intact block with little or no comminution, facilitating a relatively straight forward

Fig. 7. **a, b, c** Intra-operative lateral and AP fluoroscopic images and **d, e, f** post-op CT L knee revealing stage 1 revision fixation of posteromedial plateau status post removal of hardware and placement of a T plate with screws.

restoration of anatomy. It was suggested that the concave medial plateau generally fails with this specific pattern. In contrast, the lateral plateau is more convex and less forgiving, resulting in more comminution and depression than the medial plateau. Reduction and fixation of a medial plateau fracture component is relatively straightforward, as shown

by many recent reports on results and surgical techniques. Mal-reduction or mal-union is more likely to involve the lateral plateau, which often leads to subsequent valgus misalignment [5]. The patient often experiences a bony pivot when the lateral condyle of the femur “falls” into the lateral plateau defect. This is associated with pain and instability.

Fig. 8. **a, b** AP and lateral radiographs demonstrating anatomic reduction of articular surface. **c** Long leg alignment radiographs show restoration of native mechanical axis.

Fig. 9. Clinical follow-up at 2 years post-op, revealing full range of motion.

Despite a clear mal-union, the range of motion can be reasonable well preserved. Options at this stage are a knee replacement, arthrodesis, some type of osteotomy or a revision. While prosthetic replacement is not ideal for the young and active patient, a knee arthrodesis should only be considered a last resort. Extra-articular osteotomies will obtain a better overall alignment but generally do not address intra-articular mal-alignment. While intra-articular osteotomy surgery can be challenging, early revision can lead to better functional outcomes overall, a conclusion that has been well corroborated in the literature. Most often, the mal-union consists of a depressed portion of the weight-bearing plateau. As such, this mal-united fragment has been unloaded and has not experienced any additional wear and tear. As a result, the quality of the cartilage is often still quite good. This might explain why there are often relatively little arthritic changes of the cartilage in these mal-unions (Fig. 9).

In a large series, Kerkhoffs et al. treated 23 consecutive patients with valgus mal-union of the tibia including lateral joint depression with combined opening wedge varus osteotomy and intra-articular elevation [5]. Post-operative radiographs showed correction of the articular depression and valgus mal-alignment. At a mean 13-year follow-up, 15 patients showed no clinical or radiographic signs of osteoarthritis, four had slight progression, and two had revealed substantial progression [4]. There were no deep infections and no subsequent non-unions, and

Insall Knee Scores were rated as excellent or good for 20 patients (89%). There were, unfortunately, no post-operative CTs to evaluate intra-articular correction.

More recently, Krettek et al. reported in the German literature on the successful use of complex intra- and extra-articular osteotomies in combination with autologous cartilage cell transfer for large cartilage defects after plateau fractures [6]. Promising results were reported, but so far, we have no experience with these cell transfer techniques.

In conclusion, we have had favorable patient outcomes at our institution, when performing early revision with corrective osteotomies for the patient with tibial plateau non-union, mal-reduction, or mal-union. Good exposure and visualization of the plateau are paramount, followed by meticulous restoration of an anatomic articular surface, correction of long leg alignment with intra- and/or extra-articular osteotomies, rigid internal fixation, and bone grafting. These problems can seem intimidating and complex. However, if well planned, these surgeries most often lead to reliable healing. A successful early revision minimizes the potential for post-traumatic arthritis and will lead to better long-term functional outcomes. The literature has clearly shown that if left untreated, many of these patients will eventually progress to total knee arthroplasty. However, if performed before the onset of severe arthritis, early revision surgery as described above can be a viable alternative to total knee arthroplasty, particularly in younger, more active patients.

Compliance with Ethical Standards

Conflict of Interest: LT Dominic L. Van Nielen, MD, LCDR, Christopher S. Smith, MD, David L. Helfet, MD and Peter Kloen, MD, PhD, have declared that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

Disclaimers: The views expressed in this article are those of the author(s) and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the US Government.

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