Issue 2

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Regain Control Effectively

As per **Meta** analysis

26	20
Clinical Trial	NSAIDs

More **effective** in **reducing pain*** than other NSAIDs[1]

*Ankylosing Spondylitis

Significantly **Better** Paravertebral muscle spasm **relief**[2]

better GI safety profile and **lower** hepatotoxicity[3]

1. Wang R, Dasgupta A, Ward MM. Comparative efficacy of non-steroidal anti-inflammatory drugs in ankylosing spondylitis: a Bayesian network meta-analysis of clinical trials. Ann Rheum Dis. 2016;75:1152-1160. 2. Tüzün F, et al. Multicenter, randomized, double-blinded, placebo-controlled trial of thiocolchicoside in acute low back pain. Joint Bone Spine. 2003 Sep;70(5):356-61. 3. Laine L, Curtis SP, Cryer B, et al. Assessment of upper gastrointestinal safety of etoricoxib and diclofenac in patients with osteoarthritis and rheumatoid arthritis in the Multinational Etoricoxib and Diclofenac Arthritis Long-term (MEDAL) programme: a randomised comparison. Lancet. 2007;369:465-473.

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COMPOSITION:
Each film coated tablet contains:

Etoricoxib I.P. 60mg	Thiocolchicoside IP 4 mg
Excipients q.s.	Colours: Ferric Oxide Yellow USP-NF & Titanium Dioxide IP

INDICATIONS: For the acute treatment of inflammatory musculoskeletal disorders associated with painful muscle spasm in adults. DOSAGE AND ADMINISTRATION: 1 tablet per day taken with or without food. The treatment duration is limited to 7 consecutive days.CONTRAINDICATIONS: Hypersensitivity to Thiocolchicoside, Etoricoxib or any of the excipients of the tablet. Pregnant and lactating women, Patients with an active, or history of recurrent peptic ulcer/haemorrhage (two or more distinct episodes of proven ulceration or bleeding)., Patients who have experienced bronchospasm, acute rhinitis, nasal polyps, angioneuroticoedema, urticaria, or allergic-type reactions after taking acetylsalicylic acid or NSAIDs including COX-2 (cyclooxygenase-2) inhibitors, Severe hepatic or renal dysfunction, his drug is contraindicated in Children and adolescents, Inflammatory bowel disease, Congestive heart failure (NYHA II-IV), Patients with uncontrolled hypertension, Established peripheral arterial disease, ischaemic heart disease and/or cerebrovascular disease. WARNINGS AND PRECAUTIONS: Fluid retention, oedema and hypertension, Cautious use in patients with a prior history of gastrointestinal disease, such as ulceration and GI bleeding, hepatic disease, renal disease, hypertension, congestive heart failure, diarrhea. PREGNANCY AND LACTATION: Contraindicated ADVERSE REACTIONS: Abdominal pain, flatulence, heartburn, diarrhea, dyspepsia, epigastric discomfort, nausea, abdominal distention, acid reflux, hypertension, flushing, headache, dysgeusia, insomnia, edema, hypersensitivity reactions, including angioedema, anaphylactic/anaphylactoid reactions including shock. Sedation, drowsiness, blurred vision, constipation or diarrhea, dizziness and drowsiness, fatigue, headache, heartburn, hiccups and nausea, nervousness and confusion, dry mouth, dyspepsia (chronic or recurrent pain in the upper abdomen, upper abdominal fullness, and feeling full earlier than expected when eating), insomnia, stomach cramps, trembling, vomiting, and weakness; and possible dependence following long-term use, Photosensitivity reactions.
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Tibial Plateau Fractures in the Elderly

Krishna C. Vemulapalli, Joshua C. Rozell, Joshua L. Gary, Derek J. Donegan

With the increasing proportion of elders that make up our population [1–3], the overall incidence of tibial plateau fractures occurs in a bimodal distribution. On one end of the spectrum are low-energy or insufficiency fractures seen in this population secondary to poor bone quality [1]. At the other end of the spectrum is the classic high-energy trauma in younger population without osteopenia. As quality of life and activity level increases in the elder population, the combination of high-energy mechanisms in patients with poor bone quality has emerged. The mainstay of treatment for younger patients with tibial plateau fractures remains open reduction and internal fixation to restore normal anatomy and function and to minimize the chances of post-traumatic arthritis. However, the elder with osteopenia, medical comorbidities, and a tibial plateau fracture commonly presents with fracture characteristics that predispose to higher rates of post-traumatic arthritis including articular impaction, metaphyseal crush, and pre-existing degenerative arthritis that may limit restoration of pre-injury function [1]. We emphasize that treatment decisions must be individualized to each patient according to treating surgeon abilities and patient comorbidities and functional demands. Five treatment options have emerged: non-operative treatment, open reduction and internal fixation (ORIF), external fixation, combination of ORIF and external fixation, and acute total knee arthroplasty.

Initial Evaluation

Physical Examination

History and physical examination provide the first clues to diagnosis. Careful attention must be paid to the soft tissue envelope and neurovascular status of any patient who sustains a tibial

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plateau fracture. Damage to the soft tissues, especially the skin and subcutaneous tissue, becomes even more relevant in elder with more friable skin. The occurrence of compartment syndrome after tibial plateau fracture has been reported to be as high as 31%, with a positive correlation with fracture severity, although the incidence may be lower in the elderly [4, 5]. Even in the setting of low-energy trauma, the poor quality of elder bone can oftentimes lead to the incidence of fracture-dislocations as the osteopenic bone yields prior to the relatively lax capsuloligamentous structures of the elder knee [6]. Increased laxity will more easily allow subluxation or dislocation of the joint, which places tension on soft tissue structures like arteries, which are more calcified and delicate in the elder. Radiographs are a static picture of a dynamic process, and a joint that appears reduced on static radiographs may have been dislocated at the time of injury. This makes the evaluation of the patient's vascular status critical. The performance of ankle-brachial indices (ABI) should be routine in tibial plateau fractures with an abnormal pulse exam. An ABI<0.9 in an injured extremity warrants further vascular workup [7]. In line with common practice for all open fractures, the timely administration of appropriate antibiotics and tetanus prophylaxis is paramount [8]. As important as the initial evaluation is the continued monitoring of the soft tissues for compartment syndrome as well as evolving soft tissue injuries.

Imaging

Radiographic evaluation of tibial plateau fractures commonly begins with initial standard radiography for diagnosis followed by computed tomography (CT) of the knee to further evaluate the articular surface and extent of the fracture pattern [9]. Standard anteroposterior and lateral radiographs are the initial step when a proximal tibia fracture is suspected. Internal rotation and external rotation views can also be obtained to yield better visualization of the fracture pattern. Radiographic examination of the entire femur should be performed if knee films are negative as pain from hip injuries may be referred to the knee [10]. CT imaging is obtained once the fracture is out to length and provisionally stabilized. CT scans have been shown to significantly influence surgeon's classifications of fractures as well as potentially change the plan of treatment [11]. Multiplanar reconstruction of CT images yields superior characterization of the articular surface and the extent of fracture fragmentation. Magnetic resonance imaging (MRI) can help identify occult fractures not seen on CT scanning or plain radiographs. With diagnosed fractures, MRI allows for evaluation of the soft tissues around the knee including the collateral, cruciate ligaments, and the medial and lateral menisci. Only one patient in a series of 103 consecutive tibial plateau fractures did not have associated meniscal or ligamentous injury [12].

Goals of Treatment

The ideal management of intra-articular proximal tibia fractures will restore anatomy and maximize function. The treating surgeon should seek to first preserve life, then limb integrity, and then function. While threats to life and limb are uncommon with tibial plateau fractures, they can occur especially in older patients with less physiologic reserve [13]. Compartment syndrome can be life or limb threatening and is commonly associated with proximal tibia fractures [5, 14]. The ultimate outcome is restoration of the patient's native anatomy to preserve joint mobility, joint stability, articular congruence, and axial alignment. This should allow for pain-free motion and ambulation. With ORIF, the four factors widely accepted to contribute to long-term prognosis are the articular reduction, reconstitution of condylar width, restoration of mechanical axis, and evaluation and treatment of soft tissue pathology [15]. With older patients, the pre-injury status is paramount, as pre-existing arthritis, chronic meniscal pathology, and medical comorbidities may have impacted ambulation and function before the injury. Early mobilization of injured elders carries particular importance to mitigate morbidity and mortality. The surgeon choosing a treatment modality must consider associated compartment syndrome, soft tissue compromise, vascular injuries, and likelihood of complications and their effect on long-term function.

Non-operative Treatment

Patient Selection

The patient as a whole must be considered when developing a treatment plan. As general medical care has improved, patients are living longer, which has yielded a trauma population with an increasing number of medical comorbidities. Non-operative treatment is indicated for tibial plateau fractures that are incomplete, minimally displaced, and those that do not exhibit articular instability. Advances in anesthetic care have also changed the safety of surgery. Relative contraindications to operative treatment are cardiovascular, pulmonary, neurologic, or metabolic compromises that make general anesthesia and surgical intervention an unacceptable risk.

Certain fracture characteristics may dictate non-operative treatment. Fractures have been described as "stable" if it does not exhibit more than 10° of varus or valgus instability at any point in the arc of motion from 0° to 90° of flexion and less than 10° of instability in the frontal plane with stress [16]. Past literature has described the most common injury pattern in the elderly is the lateral split-depression and other length-stable patterns that may be more amenable to non-operative treatment [16]. Length-unstable patterns with high-energy trauma are rarely amenable to non-operative treatment.

Immobilization and Progressive Range of Motion

Non-operative treatment of a tibial plateau fracture is not synonymous with complete immobilization for an extended period of time. Schatzker *et al.* found that patients treated non-operatively with complete immobilization in a plaster cast for 1 month or longer resulted in marked stiffness of the knee once the patient was allowed to mobilize. In cases with length-stable patterns, fracture displacement was prevented with restricted weightbearing and stiffness was prevented by early controlled active range of motion in a hinged knee brace [17, 18]. The timing and the restrictions applied to how much motion should be allowed are dependent on fracture stability as incomplete or minimally displaced stable fractures may be allowed to begin range of motion from 0° to 90° immediately as tolerated by the patient. More unstable patterns may be locked in full extension in a hinged knee brace or knee immobilizer and unlocked in progressive fashion. Close clinical follow-up with radiographs is required to ensure loss of reduction does not occur and transition to operative treatment is not indicated.

Case Example

A 61-year-old female who presented 2 weeks after a medial tibial plateau fracture is initially treated non-operatively. Her fracture was non-displaced at her emergency room visit at an outside hospital but has marked loss of reduction upon presentation (Fig. 1a, b). Her knee was fixed in 30° of flexion at presentation. ORIF with structural allograft was performed, but restoration of normal medial column height was unable to be achieved (Fig. 1c, d).

Maximizing the arc of motion at the knee is needed to restore optimal function. A general goal of a 90° arc of motion at 4–6 weeks should be set. Maintaining terminal extension is paramount as delayed restoration of flexion is much more feasible than restoration of extension. Weightbearing on the injured extremity should be delayed until there is apparent radiographic consolidation of the fracture lines at which point partial progressive weightbearing may be started. Pre-injury functional status and physical therapy evaluation should dictate the need for assistive devices as many elders are at increased risk for falls secondary to medical conditions or waning strength, coordination, and balance. With careful patient selection and execution, non-operative management can be a powerful tool for managing the elder tibial plateau fracture as it obviates the perioperative and operative risks. Higher-energy, length-unstable fracture patterns should not be treated non-operatively unless the patient is chronically bedbound or non-ambulatory.

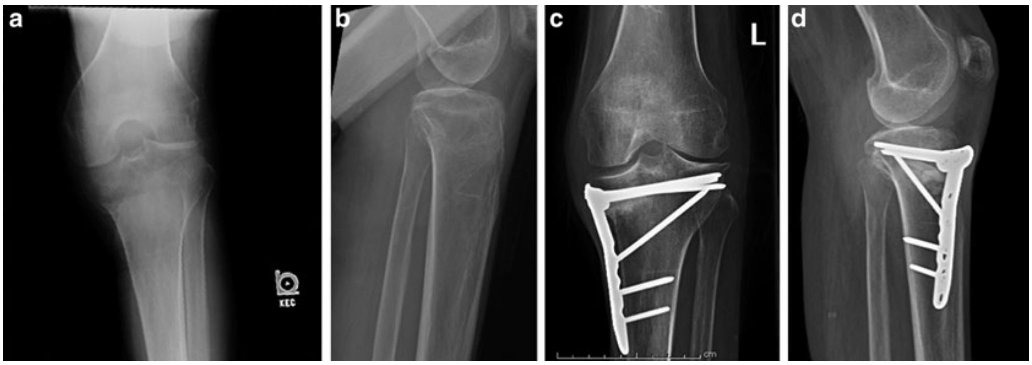

Fig. 1: A 61-year-old female who presented 2 weeks after a medial tibial plateau fracture initially treated non-operatively. (**a, b**) AP and lateral views of the knee 2 weeks post-injury. Her knee was fixed in 30° of flexion at presentation. ORIF with structural allograft was performed, but restoration of normal medial column height was unable to be achieved. (**c, d**) AP and lateral views of the knee 3 months postoperatively.

Traction

Traction has also been historically described as a modality of non-operative treatment in unstable fracture patterns in poor hosts. The application of skeletal traction can reduce the condylar fragments through ligamentotaxis; however, this will have little effect on bony fragments without soft tissue attachment, especially impacted articular fragments. A Thomas splint and Pearson knee attachment have been described as way to allow for early active knee motion while in traction. While this is a historically described technique, the practicality of prolonged traction in an elder can be called into question as the complications of prolonged bedrest in the elderly population are well known and potentially life threatening. Bed sores, venous thromboembolic disease, pneumonia, and loss of bone mass are known morbidities of bedrest for geriatric patient and may contraindicate the routine use of prolonged traction in this population [19].

External Fixation

Temporary Stabilization

Early ORIF with extensile approaches through severely traumatized soft tissues can have devastating long-term consequences with historically high rates of wound dehiscence and infections. The use of staged ORIF after temporizing external fixation for patients with compromised soft tissues near planned incisions has become common. The external fixator spans the knee and serves to maintain length, coronal, and sagittal alignment while the soft tissues heal, which is especially helpful for high-energy mechanisms. As the quality soft tissues of elders may be compromised by their age prior to trauma, careful evaluation of the soft tissue envelope must be performed to determine optimal timing for ORIF.

Indications

External fixation can be applied expeditiously with minimal physiologic trauma and in a number of scenarios is the initial standard of care. These include associated vascular injury, compartment syndrome, soft tissue compromise such as open fractures, and the polytraumatized patients where damage control stabilization is needed. Rapid restoration of length, alignment, and rotation allows for other interventions to occur.

When tibial plateau fractures are associated with vascular injury, an external fixator should be placed prior to definitive vascular repair or reconstruction. Vascular repair or reconstruction performed in the setting of a shortened, misaligned extremity can be comprised by tension once the limb is reduced. Temporary vascular shunts should be used to restore flow while the often long and difficult vascular procedure is completed. The orthopedic surgeon should ideally perform the four-compartment fasciotomies, as the placement of these incisions will affect options for later reconstruction.

Spanning external fixation allows ample access to wounds from open fractures or fasciotomy sites and allows serial debridements and dressing changes [20]. Hak *et al*. reported no significant increase in infection rates when applying definitive surface implants in the setting of open fasciotomy wounds as long as thorough debridements were carried out prior to the final surgery [14].

A concern with temporary external fixator placement is the potential for pin site-plate overlap and infection. Placement of tibial pins for temporizing external fixators should generally be below the distal extent of planned plate; however, the surgeon must ensure adequate stability exist as moving pins further from the injury decreases the stiffness of the construct. The scientific evidence is conflicting. Laible *et al*. found no correlation with overlap of a plate and pin site from a temporizing fixator in a series of 79 tibial plateau fractures [21]. However, this may have been underpowered. In a series of 182 patients, Shah *et al*. showed a statistically significant higher rate of deep infection when definitive plates overlapped with pin sites compared with plates that did not overlap pin sites [22]. We believe placement of pins outside the zone of injury and planned plate should be done unless adequate stability cannot be achieved.

Definitive External Fixation

Severe injuries with significant soft tissue loss either from trauma, ischemia, or compartment syndrome raise concern for deep infection. While plates and screws may provide excellent mechanical stability, the formation of a biofilm on a plate should concern the physician. Musculoskeletal infections associated with implants cannot be cleared without implant removal, and the biofilm itself affects osteoblast and impairs bony healing [23]. In these scenarios and in patients who are deemed poor candidates for internal fixation for other reasons, the option for definitive external fixation is enticing. The techniques of uniplanar external fixation, hybrid small-wire fixators, and ring external fixation can achieve the stability necessary for healing while minimizing iatrogenic soft tissue dissection. SF-36 scores similar to age-matched controls at an average of 3-year follow-up have been reported with articular ORIF and definitive uniplanar external fixation of the metaphyseal portion of the fracture [24]. Half-pins close to the knee joint can lead to septic arthritis that necessitate knee arthrotomy and debridement [24]. Infected wires or half-pins that are not intracapsular can be treated with removal, which can often be done in the clinic without general anesthesia.

We use a technique of knee-spanning external fixation that is converted to a "T-bar" external fixator at 6–8 weeks post-injury once metaphyseal healing has begun. ORIF of the articular block is performed, if needed, in the first 2 weeks after injury. A manipulation under anesthesia (MUA) is performed with conversion from spanning to "T-bar" external fixation while under anesthesia, and range of motion is initiated immediately after surgery.

Case Example

A 63-year-old male who jumped out of a window at a psychiatric hospital sustained a Schatzker VI tibial plateau fracture and presented with compartment syndrome (Fig. 2a, b, Video 1). He

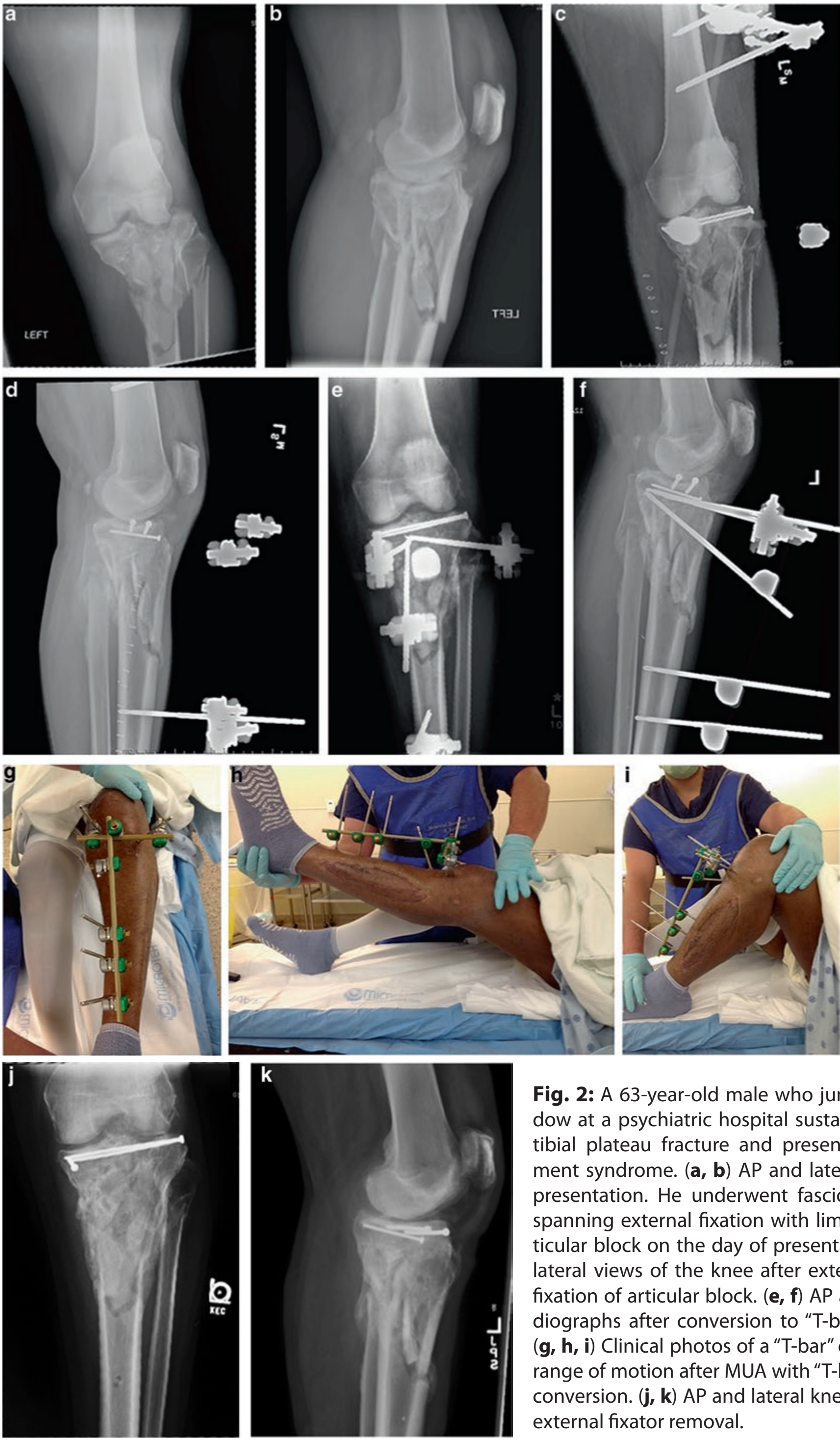

Fig. 2: A 63-year-old male who jumped out of a window at a psychiatric hospital sustained a Schatzker VI tibial plateau fracture and presented with compartment syndrome. (**a, b**) AP and lateral injury X-rays on presentation. He underwent fasciotomies and knee-spanning external fixation with limited ORIF of his articular block on the day of presentation. (**c, d**) AP and lateral views of the knee after external fixation screw fixation of articular block. (**e, f**) AP and lateral knee radiographs after conversion to "T-bar" external fixator. (**g, h, i**) Clinical photos of a "T-bar" external fixator and range of motion after MUA with "T-bar" external fixator conversion. (**j, k**) AP and lateral knee radiographs after external fixator removal.

underwent fasciotomies and knee-spanning external fixation with limited ORIF of his articular block on the day of presentation (Fig. 2c, d). He subsequently underwent conversion to a "T-bar" external fixator once metaphyseal healing was evident at 6 weeks post-injury (Fig. 2e–g, i). His external fixator was removed at 3 months post-injury and weight bearing was immediately begun.

Ring and hybrid external fixators are also powerful tools in the armamentarium of a surgeon experienced with these techniques. Articular reduction can be attained through a traumatic wound or through percutaneous means with limited internal fixation with olive wires to capture and compress condylar fragments. Then by using a combination of diverging tensioned wires in the periarticular region and half-pins in the diaphysis, it is possible to achieve an adequate reduction and stable construct [25–27] or a spatial frame [28]. Outside of the obvious advantages of this technique with regard to soft tissue stripping and deep infection risk, the Ilizarov constructs allow for progressive correction of rotational and translation deformities as well as sequential compression through the frame without requiring return trips to the operating room. It is also possible to allow for early range of motion at the knee and early partial weightbearing with properly constructed frames as long as fracture stability is obtained.

Ferreira *et al*. conducted a retrospective review of 46 patients with a mean age of 43 years who sustained bicondylar tibial plateau fractures which were treated with a four-ring frame consisting of three full rings and a two third proximal ring to allow for knee flexion postoperatively. In this study the articular surface was reduced through closed means or with a 2-cm midline incision, and a single 6.5-mm cannulated screw was inserted into the subchondral bone to stabilize the articular surface. Postoperatively patients were able to undergo active-assisted knee range of motion and were encouraged to mobilize with full weightbearing as tolerated. All fractures in this study united without loss of articular reduction with only one patient requiring a second procedure for autologous bone grafting with a 100° arc of motion at final follow-up. Pin site infection was the most common complication; however, none of the patients developed soft tissue complications, wound dehiscence, infection, osteomyelitis of the fracture, or septic arthritis [29].

The Canadian Orthopaedic Trauma Society (COTS) performed a multicenter, prospective, randomized clinical trial in which ORIF with dual plating was compared to limited internal fixation and application of a circular fixator for displaced bicondylar tibial plateau fractures [30]. The group concluded that patients in the external fixator group had statistically significantly less intraoperative blood loss and shorter hospitalization stays without significantly different articular reductions. There was a trend toward superior early patient-derived functional outcomes and ability to return to pre-injury activities at 6 months with circular fixation that disappeared at 2-year follow-up. There were no significant differences in arc of knee motion and Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores for pain, function, or stiffness between the two groups at final follow-up. The circular fixator group had significantly lower bodily pain scores, and the number of unplanned repeat surgical interventions was greater in the internal fixation group. While this study provides support with regard to the benefits of definitive external fixation, this study predates the advent of modern proximal tibia locking plates, and the surgical approaches were at the discretion of the operating surgeon [31].

Case Example

A 61-year-old female sustained a bicondylar tibial plateau fracture after an all-terrain vehicle accident. She underwent spanning external fixation and emergent fasciotomies at an outside hospital (Fig. 3a–d). She was taken for ORIF of her articular block prior to skin grafting of her lateral fasciotomy wound and closure of her medial fasciotomy wound (Fig. 3e, f). A Taylor spatial frame (TSF) was placed at 6 weeks post-injury after her skin graft had been taken and matured. Weightbearing with assistive devices and knee range of motion was begun at this time (Fig. 3g, h). The TSF was removed at 15 weeks post-injury (Fig. 3i, j).

Fig. 3 (**a, b**) AP and lateral radiographs in spanning external fixation. (**c**) Axial image of articular surface of proximal tibia. (**d**) Sagittal image of joint depression on lateral tibial plateau. (**e**) Intraoperative elevation of articular depression and provisional stabilization with Kirschner (K) wires. (**f**) Calcium cement augmentation of metaphyseal void with screw stabilization of articular block. A Taylor spatial frame (TSF) was placed at 6 weeks post-injury after her skin graft had been taken and matured. (**g, h**) AP and lateral view of the knee after TSF placement. (**i, j**) AP and lateral views of the knee after TSF removal.

Limited Open Reduction and Percutaneous Screw Fixation

Arthroscopically Assisted Treatment

Knee arthroscopy is an established component of treating knee pathology and even fractures for quite some time. The idea of arthroscopically assisted tibial plateau reduction and internal fixation (ARIF) has become a popular topic within recent years. Roerdink *et al*. treated 131 consecutive patients with ARIF and retrospectively identified 30 patients over the age of 55 [32]. They found that in this cohort, secondary displacement occurred in 9 of the 30 fractures but only in 1 of 12 of those treated with a bone substitution substrate ($p = 0.049$). At the final clinical evaluation at 5 years, there were 12 excellent, 12 good, 3 fair, and 3 poor results as evaluated by the Rasmussen score. Interestingly there was no statistical difference between those patients in which secondary displacement occurred and those in which it did not [32]. While there are few studies that suggest that ARIF may be superior to ORIF, there are no prospective randomized trials to show a clear benefit for ARIF over ORIF [33, 34]. The key to success with this technique is fracture selection, as not all fractures are amenable to fix with a limited approach. The purported advantages of this technique include minimal dissection yet direct visualization of the articular surface for reduction and quicker recovery. Soft tissue injuries of the anterior/posterior cruciate ligaments or menisci can also be readily identified and addressed at the time of fracture fixation, which may aid in rehabilitation and decrease the need for future surgeries.

Fracture patterns that have been identified as amenable to this technique predominantly appear to be Schatzker type II and III injuries as well as those relatively simple fracture patterns that have an associated intercondylar eminence avulsion fracture. All of these patterns are associated with largely intact cortices or the "cortical envelope" as Levy *et al*. describe [35]; percutaneous reduction and stabilization of medial or lateral condyles can restore the envelope if needed. Fragmentation of this cortical envelope may preclude a fracture from being amenable to ARIF and is a situation in which some other form of fixation should be considered. This technique should be thought of as an adjunct to the traditional approach of fracture fixation as it should be used in conjunction with intraoperative fluoroscopy and articular reduction. Fracture fixation should still be achieved through the use of a bone tamp for elevation of the depressed fracture fragments through a cortical window, provisionally held with K-wires, definitively fixed with cannulated or cortical screws with washers, and backfilled with a bone-void filler. The use of a kickstand or buttress screw at the apex of the fracture is recommended for achievement of a biomechanically stable construct that will not only secure the articular surface with subchondral placement of lateral to medial rafting screws but also buttress the shear component when a vertically oriented fracture line is present. Intercondylar eminence fragments can be reduced and fixated with non-absorbable sutures through bone tunnels and tied around a post or interference fit screw.

Compartment syndrome from the increased fluid burden in the joint capsule and potential for extravasation into the surround soft tissues has long been the concern with arthroscopically assisted techniques for trauma. Recent experience has not supported this concern with a low incidence of compartment syndrome with this technique [33]. Regardless, constant vigilance is recommended due to the devastating consequences of a missed compartment syndrome, and fasciotomies should be performed when indicated.

Percutaneous Screw Placement

The technique for placement of percutaneous screws under fluoroscopic guidance without arthroscopic assistance is also possible for amenable fracture patterns. Simple Schatzker type I and possibly IV patterns that are minimally displaced with minimal to no discernible joint depression may be treated with percutaneous placement of cannulated screws with washers by way of lag by design or lag by technique methods. Fluoroscopy is used to assess reduction intraoperatively. As described above, the placement of a kickstand or buttress screw can be used in this setting for additional support. The benefits of this technique are the same as any of the approaches that limit dissection with potential for less iatrogenic soft tissue insult and quicker recovery. These minimally invasive techniques may also be performed earlier as no large incisions are required.

In amenable fracture patterns, minimally invasive techniques can be greatly beneficial in the elderly population. They limit iatrogenic soft tissue damage in a patients who at baseline may have poor soft tissues, reduce anesthesia time and multiple trips to the operating room in patients with multiple medical comorbidities, and allow for potentially quicker recovery and mobilization in a subset of patients for whom the grave complications associated with prolonged immobilization are well documented [19].

Percutaneous Cement Augmentation

Evangelopoulos *et al*. have suggested percutaneous cement augmentation for treatment of insufficiency fractures of the tibial plateau in elderly patients [36]. This technique evolved from the well-described technique of kyphoplasty or vertebroplasty for vertebral compression fractures. In this small series, five patients with seven non-traumatic fractures of the tibial plateau were treated by using a vertebroplasty cannula to tamp up the joint depression, and then the underlying metaphyseal region was backfilled using polymethyl methacrylate (PMMA) cement. These patients were allowed to initiate full weightbearing immediately after surgery, and the median length of stay in the hospital was 2 days for these five patients with no loss of reduction noted at 12-month follow-up. The applications for traumatic fractures associated with osteopenic bone remain unstudied.

Open Reduction and Internal Fixation

Open reduction and internal fixation remain the gold standard of treatment for physiologically young patients that can tolerate the burden of anesthesia and surgical risks associated with approaches needed to reduce and stabilize the fracture. In older patients, three questions must be asked prior to proceeding with surgical fixation:

1. Can the elder tolerate the anesthesia and blood loss anticipated?
2. Will the surgeon be able to obtain and maintain a reduction?

3. Will the surgical outcome improve the patient's function?

Older age and osteopenia are factors known to increase the risks of malreduction, post-traumatic arthrosis, and the need for subsequent total knee arthroplasty (TKA) [1, 37]. The components of a successful surgical outcome are reliably restoration of the mechanical axis, reconstitution of condylar width, anatomic articular reduction, knee stability, and evaluation and treatment of meniscal pathology [15]. The surgeon must consider his or her ability to achieve these goals in elderly patients.

Surgical Planning

An intimate knowledge of the anatomy of the tibial plateau, the structures that reside in this region, and the morphology of the fracture is critical to surgical planning. The role of plain radiographs and CT has been previously described, and these images should be readily available in the operating room at the time of surgery. First and foremost, the soft tissue envelope and patient's general medical condition should be optimized prior to ORIF. Certain patients, especially those with low-energy mechanisms, may be ready for ORIF shortly after injury. However, there should be a low threshold for delaying definitive fixation with or without external fixation if needed.

In patients with open fractures, vascular repairs, or fasciotomies, careful multidisciplinary coordination is required to ensure that hardware is not exposed for an extended period of time. The surgeon may elect to delay ORIF until all soft tissues have healed. Most vascular surgeons utilize a posteromedial approach in this region, and it is essential to consider the placement of this wound and its status when making a preoperative plan. We advocate orthopedic involvement in the placement and closure of these wounds.

Colman *et al*. have shown that extended operative time is associated with increased rates of infection, and having the necessary equipment in the room is essential to ensuring time is not wasted [38]. A large C-arm is routinely used in these procedures and each individual's anatomy is slightly different. Fluoroscopic images of the contralateral knee may also be taken in the operating room prior to incision and may be used as a way to judge reduction. An Arbeitsgemeinschaft für Osteosynthesefragen (AO) universal distractor can be used to restore length or create angular deformity to improve articular visualization with a submeniscal arthrotomy *Planning*.

Surgical Approaches

A number of strategies have been described when approaching tibial plateau fractures. The fracture morphology should guide the choice of surgical approach or approaches. Consideration of future approaches for arthroplasty in the elder population should be given.

The anterolateral approach is one of the most commonly utilized given the epidemiology of tibial plateau fractures with the lateral plateau being the side more commonly involved [1, 18, 37]. The incision utilized is a "lazy S" centered over Gerdy's tubercle. A submeniscal arthrotomy can be performed just above the joint line to visualize intra-articular segments.

The posteromedial approach is often utilized when faced with a medially based fracture fragment in isolation or as a component of a more complex injury. A gentle curvilinear incision approximately 1 cm posterior to the posteromedial border of the tibia is used. The surgeon may elevate and "work under" the pes anserinus tendons or transect them (with later repair). The medial collateral ligament (MCL) is identified deep to the pes anserinus and should be preserved for ligamentous stability. If direct visualization of the medial articular surface is required, we recommend vertically splitting the MCL with the underlying fracture to prevent valgus instability of the knee. The popliteus muscle can be identified posteromedially and detached subperiosteally to expose the posteromedial tibial plateau.

Barei *et al*. have demonstrated that a combination of anterolateral and posteromedial approaches is a safe and effective way to address fracture patterns that require access to both the medial and lateral condyles [15, 39]. Special care should be taken to ensure that there is an adequate skin bridge between the medial and lateral incisions to minimize the potential for wound complications over this relatively sparse soft tissue region.

A midline anterior incision has also been described by Espinoza-Ervin *et al*. that utilizes an incision similar to that used in total knee arthroplasty with a medial parapatellar arthrotomy [40]. Long incisions are recommended with the development of full-thickness fasciocutaneous flaps medially and laterally. The benefits of this approach are focused on the ability to leave a simple and familiar scar that is easily used if further surgeries are required, particularly those in the hands of arthroplasty surgeons who frequently utilize this incision. However, the approach precludes placement of a posteromedial buttress plate.

Reduction Techniques

Both direct and indirect means of reduction are used to reestablish pre-injury anatomy. Spanning external fixation and the AO universal distractor are indirect means to obtain length. Elevation of depressed osteochondral articular fragments requires some form of direct manipulation, whether open or percutaneous. Arthroscopy, fluoroscopy, and/or surgical arthrotomy is used to visualize reduction at the articular surface. "Balloon tibioplasty" with kyphoplasty instrumentation has been described as a percutaneous technique [41]. Provisional fixation with wires can be used prior to backfilling of the metaphyseal defect and definitive fixation. "Rafting" screws can be placed just caudal to subchondral bone of the proximal tibia, independently or through the proximal row of a plate to support articular reduction.

Bone Graft and Bone Graft Substitutes

Reduction of depressed articular fragments leaves a bony void where metaphyseal bone was crushed at the time of injury. This void should be filled to support the articular surface and decrease subsidence; this is generally done with bone graft or a bone substitute. Impaction bone grafting with either autogenous metaphyseal bone graft or allograft chips is a well-described technique [42]. Use of cancellous allograft chips avoids the potential morbidities of open bone graft harvest.

Bone graft substitutes avoid both potential donor-site morbidity and risks of infectious disease transmission through allograft tissue. McDonald *et al*. conducted a cadaveric biomechanical study that compared the fragment displacement and compressive stiffness of lateral split-depression type tibial plateau fractures treated with autogenous femoral head bone graft versus calcium phosphate. After cyclical fatigue loading, the fractures treated with calcium phosphate showed a statistically significant decrease in fragment depression and a greater ultimate load to failure when compared with the group treated with bone graft [43]. A multicenter randomized, prospective trial comparing iliac crest autograft to calcium phosphate cement for metaphyseal defects in tibial plateau fractures showed less articular subsidence at 3- and 12-month follow-up [44]. We recommend calcium phosphate cement based upon available evidence, but studies have not yet shown a difference in functional outcomes in the long term.

Fixation Techniques

Locking plate technology has changed the ability to create stable constructs in metaphyseal and/or osteopenic bone [1–3]. Anatomic pre-contoured plates allow simpler application of surface implants about the proximal tibia. Aiming arms for distal screws have been designed to allow for percutaneous screws in the tibial shaft.

The operating surgeon will choose the function of any plate utilized. Simple, vertical fracture lines are best fixed with buttress plates that create an axilla at the apex of the fracture line and resist shear. Comminuted metaphyseal fractures are spanned after functional reduction of length, rotation, and alignment with bridge-plating techniques. Locking technology is not required to create many of these constructs. No statistically significant difference has been shown between functional outcomes of patients managed with locked plates versus non-locked plates [45, 46]; however, locking screw technology improves fixation in metaphyseal or osteoporotic bone.

Case Example

A 64-year-old male presented after motor vehicle collision with a Schatzker VI tibial plateau fracture/dislocation with a tibial tuberosity component (Fig. 4a, b). Spanning external fixation was performed with ORIF delayed until 10 days post-injury (Fig. 4c–i). The patient healed uneventfully and returned to full pre-injury function (Fig. 4j, k).

There are numerous studies that show satisfactory results for tibial plateaus in the elderly that were treated with ORIF. Schatzker *et al*. found that 78% of a population of patients with a mean age of 57 were found to have satisfactory results at 2.3 years [18], and Rasmussen similarly reported an 87% acceptable result after surgery in patients with a mean age of 55 years [47]. Both of these studies were conducted well before the advent of modern-day plates and locking technology and show that reduction and stable fixation lead to satisfactory outcomes [37, 48]. In 2004 Su *et al*. found that 87.2% of patients with an average age of 67 years who were treated with ORIF for a tibial plateau fracture were found to have excellent or good clinical results, similar to the studies in younger populations [37]. Rademakers *et al*. followed 109 tibial plateau fractures for 5–27 years

Fig. 4: A 64-year-old male presented after motor vehicle collision with a Schatzker VI tibial plateau fracture/dislocation with a tibial tuberosity component. (**a, b**) AP and lateral views of the knee on presentation. (**c**) Axial CT cut of the articular block of the proximal tibia in spanning external fixation. (**d**) Stabilization of the articular reduction with multiple lateral to medial K-wires. (**e**) Provisional stabilization of the medial column with K-wires. (**f, g**) Application of a posteromedial buttress plate. (**h, i**) Final AP and lateral views after addition of a lateral locking plate and independent lag screws for the tibial tuberosity component. (**j, k**) Clinical photos of the knee in extension and flexion at 1-year follow-up.

and found that the basic principles for surgical treatment are the same in elderly patients as for young patients, though they believe that a more conservatively oriented rehabilitation program is mandatory for this population [48].

A few studies have also concluded that the radiographic outcome in the elder does not correlate with their clinical outcome, which may speak to the importance of early mobilization and rehabilitation to quickly return to pre-injury activity [37, 49]. When investigating prognostic factors for a successful outcome after fracture fixation, age at the time of injury was consistently found to have a negative correlation with outcome, and Frattini *et al*. also identified female gender and fracture severity as negative predictors of prognosis [1, 37, 50]. Predictably, failure to achieve and maintain reduction of the depressed fracture fragments in the elder plateau was the most important factor associated with accelerated degeneration, as valgus and varus deformity develops readily from joint depression [6].

Acute Total Knee Arthroplasty

Total knee arthroplasty for post-traumatic arthrosis is a well-documented procedure for the sequelae of a tibial plateau fracture. The conversion after ORIF is fraught with complications when compared to a primary TKA for degenerative arthritis. Increased rates of stiffness, wound breakdown, superficial and deep infection, patellar subluxation, hematoma, DVT, ligamentous deficiency, and reflex sympathetic dystrophy are seen after conversion to TKA after ORIF [51, 52].

Acute distal femoral replacement for elders with distal femur fractures are being implanted in selected patient populations as an acute surgical treatment to allow immediate weightbearing. The long-term outcomes remain unknown. The role of acute total joint arthroplasty in the setting of a tibial plateau fracture is less clear. While successful acute total knee arthroplasty for tibial plateau fracture would prevent the development of post-traumatic arthritis, injury and patient factors may limit the ability to achieve successful joint replacement. Benazzo *et al*. describe the technique of acute total knee arthroplasty for tibial plateau fractures and highlight the need for adjunct fracture fixation, the use of augments, or the need for stemmed prostheses at the time of the arthroplasty in order to provide a stable platform for the prosthesis to function and limit subsidence [53]. They go on to note that this technique may not be feasible for bicondylar fractures or fractures that involve the tibial tubercle due to the compromise of the extensor mechanism. Kini *et al*. have a series of six lateral tibial plateau fractures and three proximal tibial shaft fractures that were treated with acute navigated TKA, and they reported good success with this technique with a mean Knee Society Score of 84 at a mean follow-up of 26 months [54]. Regardless, the surgeon should not expect nor quote the patient results of primary TKA if replacement is used acutely for tibial plateau fractures. At this time, the role of acute TKA in the setting of a tibial plateau fracture and its feasibility still appears unclear.

Complications

Wasserstein *et al*. conducted a retrospective review of 8426 patients with operatively treated tibial plateau fractures and found that while the overall 90-day mortality of this cohort was 0.85%, the odds of mortality increased 11% for each year older than 18 years at the time of injury [51]. Patients older than 80 years had an 8.2% 90-day mortality rate [51]. A strong association between age and failure of fixation was found in one study where 85% of patients with failed fixation were older than 60 years and every patient with osteoporotic bone had failure of fixation [55]. No correlation between increasing age and infection has been shown [55].

Conclusions

Non-operative treatment, definitive forms of external fixation, open reduction and internal fixation, and acute total knee arthroplasty are all methods of treating geriatric tibial plateau fractures. We recommend the geriatric patient be treated with a similar algorithm as the younger patient. Excellent articular reduction and stabilization should be paired with a functional reduction of the metaphysis. Certain patient and injury factors may lead to choice of less invasive treatments. Individualizing the treatment plan based upon the uniqueness of each patient and fracture is required.

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Adding a Bone Graft to Reverse TSA

Jesse W. Allert, Mark A. Frankle

Case Presentation

The patient is a 79-year-old active male with a 17-year history of progressive right shoulder pain. A retired police officer, the patient recalls several injuries over the course of his career, all of which were managed conservatively and none of which are acute. The patient now lives alone and finds himself unable to elevate his arm over his head. He is also unable to sleep without waking numerous times from pain in the shoulder. After failed conservative management, the patient was indicated for reverse total shoulder arthroplasty.

On physical examination, the patient appears younger than stated age and is right hand dominant. He has forward elevation to 60° and external rotation to neutral. He has significant crepitus and pain throughout range of motion and has noticeable weakness in flexion and external rotation.

Four radiographic views show superior migration of the humeral head in association with superior wear of the glenoid, consistent with advanced rotator cuff arthropathy. As part of routine preoperative evaluation, the patient received computed tomography with axial, coronal, and sagittal imaging. The supplemental 3D imaging can be seen in Fig. 1.

Diagnosis/Assessment

The patient's history, physical, and radiographic findings are consistent with the diagnosis of rotator cuff arthropathy. While there are many options for patients with a massive rotator cuff tear, this patient had notable superior migration with glenohumeral arthritis, making him an excellent candidate for reverse total shoulder arthroplasty. The uncontained defect of the superior glenoid is discussed as part of the patient's preoperative planning, and in this case it was determined that the patient may require intraoperative grafting to optimize glenoid positioning and fixation.

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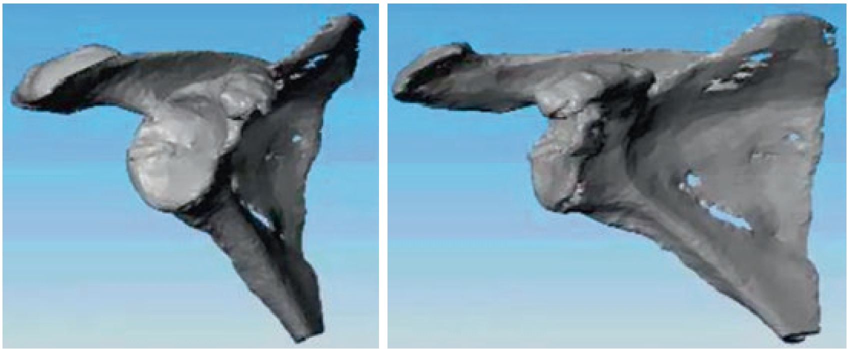

Fig. 1: Three-dimensional reconstruction of routine preoperative CT imaging. With advanced imaging, the superior bone loss can be better quantified and utilized for preoperative planning.

Management

A routine deltopectoral approach was performed. The subdeltoid, subacromial, and subcoracoid spaces were released. A subscapularis tendon peel off of the lesser tuberosity was performed and the appropriate humeral head cut was made. A standard circumferential release was completed along the rim of the glenoid, taking care to protect the axillary nerve. In this case, the glenoid revealed the expected uncontained superior defect.

Using the CT imaging and the visualized inferior glenoid as a guide, the 2.5 mm drill bit was used to drill bicortical until the tip exited the anterior scapula (Fig. 2). The hole was measured to assure an adequate depth of greater than 25 mm. Along the same trajectory as the drill bit, a 6.5-mm guide tap was placed (Fig. 3). This was used as a guide for reaming. The native inferior glenoid was reamed down to cortical bone, while the superior defect was left untouched (Fig. 4). The surface bone of the defect can be prepared with a motorized burr to provide a roughened surface to receive the graft.

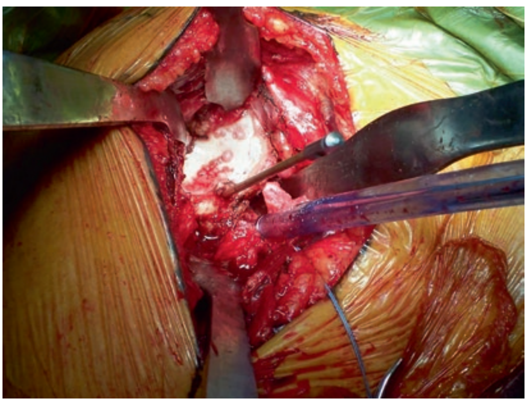

Fig. 2: Right shoulder with drill bit placed in the center of the glenoid.

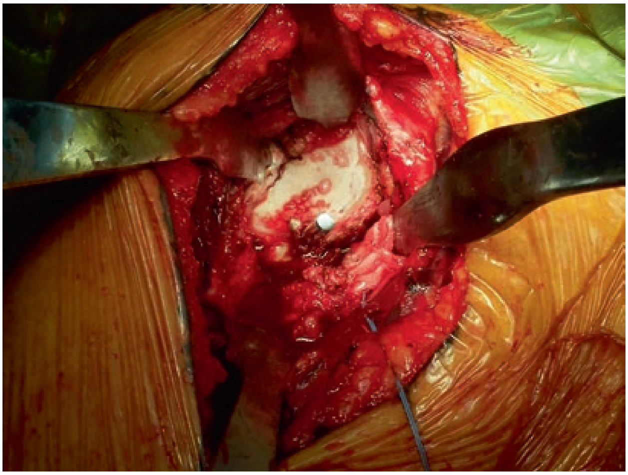

Fig. 3: The tap is inserted along the same trajectory as the drill bit.

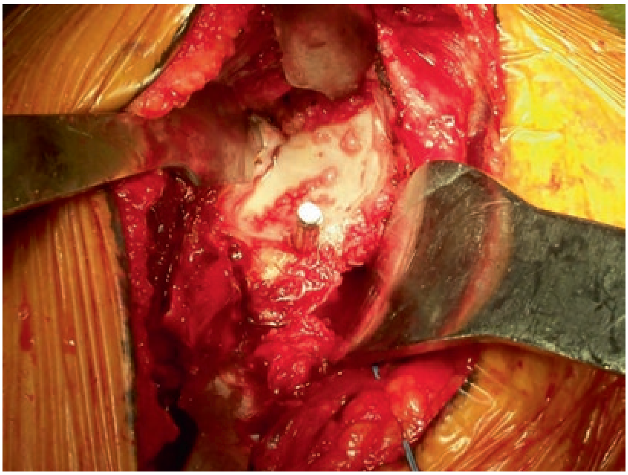

Fig. 4: The inferior portion of the glenoid is reamed to bleeding bone. The superior portion with significant bone loss is noted and used as a guide to shape autograft from the humeral head cut.

On the back table, the humeral head was prepared and shaped to match the defect. The cartilaginous surface serves as the outer portion of the glenoid, while the remainder of the head is prepared to later receive the baseplate. First, the graft is fixed to the native glenoid using multiple Kirschner wires that will not obstruct placement of the reamer (Fig. 5). Once the autograft is securely fixed, it was reamed to the same depth as the previously reamed native glenoid (Fig. 6). The baseplate was then placed, the wires removed, and peripheral screws placed (Fig. 7). A glenosphere that was hooded to cover more of the baseplate was impacted directly onto the graft to enhance both fixation and compression (Fig. 8).

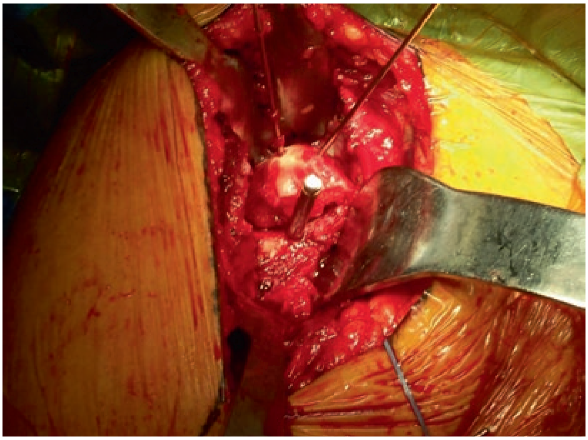

Fig. 5: The humeral head autograft is inserted using multiple points of fixation.

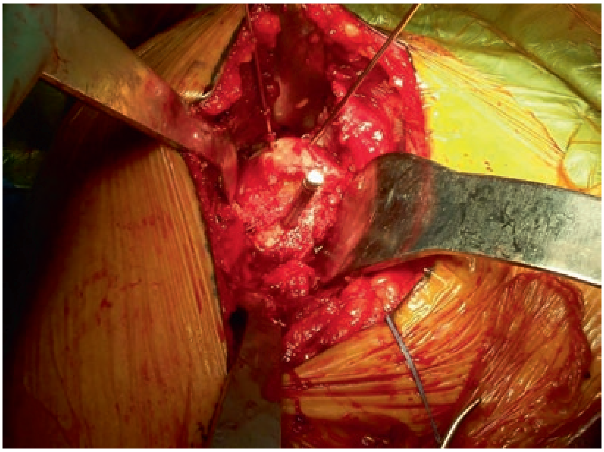

Fig. 6: The graft is reamed to the depth of the previously reamed native glenoid.

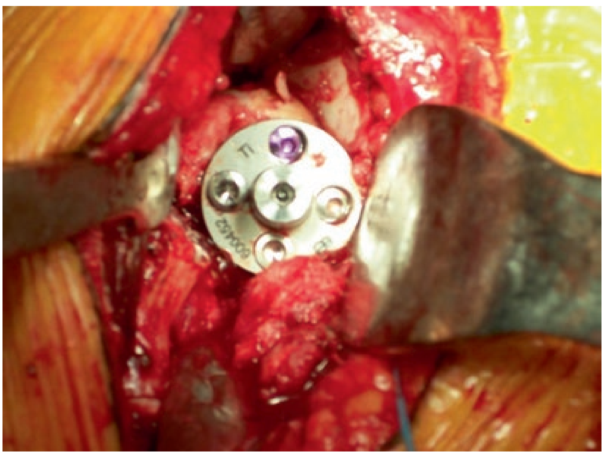

Fig. 7: Baseplate is placed along with peripheral screws.

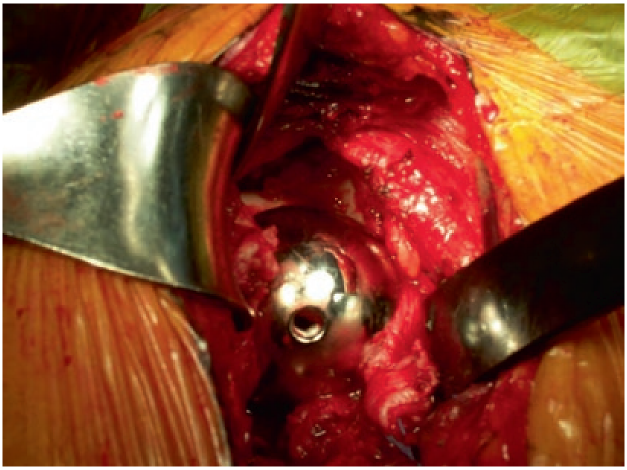

Fig. 8: Glenosphere placement.

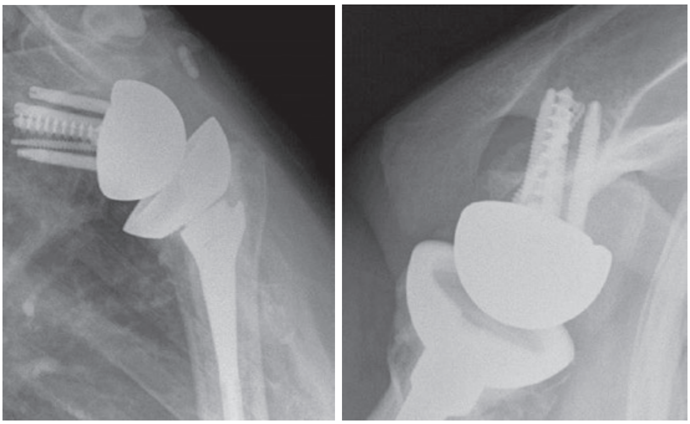

Fig. 9: Postoperative X-ray imaging

Outcome

This 79-year-old male with significant limitation in preoperative range of motion went on to have forward flexion to 150°. At 5 years postoperative, his glenoid shows no radiographic evidence of glenoid component loosening (Fig. 9).

Literature Review

Much has been written with regard to bone deficiency in the anatomic total shoulder arthroplasty and arthroplasty in the revision setting. There is however much less documented with regard to bone grafting in primary reverse total shoulder arthroplasty [1, 2]. Techniques include preferential reaming, bone grafting, and using custom or patient-specific instrumentation. While preferential reaming of the "high side" in this case may aid in correcting version, it would medialize the implant and remove more bone. Significant medialization can play a role in a more notable cosmetic deformity and even alter the compressive forces of the deltoid and increase dislocation rates [3–6].

In primary reverse total shoulder arthroplasty, the native humeral head can provide an excellent source of autograft without increasing morbidity. This autograft is frequently prepared as cancellous bone chips and when there is no bone loss is placed in the intramedullary canal of the humerus to enhance fixation of the humeral stem. In the setting of glenoid bone loss, a structural allograft can be created and compressed at the implant-bone interface to increase surface area and fixation. Glenoid bone stock can be maintained and the autograft can be reamed alongside the native glenoid.

Clinical Pearls/Pitfalls

- Maintain multiple points of fixation of the graft to native bone during reaming. This will keep the graft from spinning and being damaged by the reamer.
- A hooded glenosphere may be used to aid in graft compression. The hood can be oriented directly over the graft and impacted, providing additional compressive forces in addition to the baseplate.
- Err on oversizing the graft during preparation. A larger graft can always be further pared down after fixation. Undersizing the graft can decrease structural integrity and make it susceptible to inadequate fixation or breaking during preparation.
- Initially the 6.5 mm tap can be used on power to better find the trajectory of the previously placed 2.5 mm drill bit. Once the tap engages, a t-handle can be used manually to get a more tactile feel of the glenoid bone stock. As a guide that the bone is stout enough, some resistance should be detected while turning the t-handle.

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Management of Periprosthetic Femur Fracture

Alfred J. Tria, Jason M. Jennings, Raymond H. Kim, Aldo M. Riesgo, William L. Griffin

Introduction

Alfred J. Tria

Periprosthetic femur fractures are the most common fracture that leads to total knee arthroplasties [1]. The evaluation of the injury must first consider whether the fracture is displaced or not. The undisplaced fracture can be treated nonoperatively with various external supportive devices. The displaced fracture will require operative intervention in order to allow ambulation and subsequent range of motion activities. If the fracture is displaced, the femoral component must be eval uated for stability. If the component has enough underlying bone attached to it, fixation with component preservation may be possible. The fixation can involve either intramedullary rod fixation or an external plate technique. If the femoral component is completely loose from any underlying bone, replacement is the only alternative. The area of debate concerns the value of internal fixation versus replacement when there is that clinical choice [2]. Internal fixation preserves the original implant but exposes the patient to a longer period of recovery and possible nonunion [3]. Total replacement is much more invasive but may be more predictable [4]. There are no large series that

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compare these two techniques. The case presentations here will review the options and clarify the results that are available at the present time.

Option 1: Management of Periprosthetic Femur Fracture—Open Reduction Internal Fixation (ORIF)

Jason M. Jennings and Raymond H. Kim

Case Presentation

History

A 72-year-old female presented 10 months after an uncomplicated left total knee arthroplasty with a distal femoral periprosthetic fracture. The patient reported a ground level fall off of her motorized scooter which caused her to land directly onto her left knee. There were no other associated injuries.

Physical Examination

Examination of the patient's left lower extremity revealed superficial abrasions over her anterior knee from a fall. Her motor function was grossly intact distally; however, sensation was markedly decreased throughout the foot secondary to preexisting neuropathy. She had 2+ dorsalis pedis and posterior tibial pulses, and her foot was well perfused. Her previous anterior midline incision was well healed. Her thigh and lower leg compartments were soft and compressible. The remainder of the physical examination was deferred secondary to her fracture; however, previous clinical notes revealed her preinjury range of motion was 3–115° with central patellar tracking and no signs of instability.

Radiographs and Advanced Imaging

Two views of the distal femur were obtained which demonstrated a distal femur periprosthetic fracture without signs of implant loosening (Figs. 1 and 2). Advanced imaging was not performed for this case; however, if there is uncertainty regarding extension of the fracture into the implant, the authors have a low threshold to obtain a computed tomography (CT) scan.

Surgical Approach

The patient is placed in a supine position on a radiolucent table with a bump under the ipsilateral extremity. A lateral-based incision is utilized distally to allow exposure over the distal femoral condyle for placement of the distal femoral locking plate through a minimally invasive approach. Direct visualization of the fracture is not required. The iliotibial band is split, and the vastus lateralis

Fig. 1: Attempted anteroposterior (AP) view of the of the distal femur demonstrating a distal.

Fig. 2: Lateral view demonstrating the distal femoral fracture without signs of implant loosening.

is elevated with an emphasis on minimal soft tissue disruption. The implant is inspected to assure there are no signs of loosening which should confirm what has been observed with preoperative radiographs and advanced imaging such as a CT scan if indicated. An appropriate size distal femoral locking plate is selected and placed from distal to proximal in a submuscular fashion to avoid extensive soft tissue stripping until the most distal portion of the plate is oriented properly on the lateral condyle. The aiming arm, which allows for the proximal insertion of screws percutaneously, may be placed at this time or after fracture reduction. We have found it advantageous in larger patients to attach the aiming arm after insertion of the plate to avoid impinging the lateral soft tissues during insertion. Fluoroscopic imaging may be indicated to determine the length of the plate and to assure that it is resting distal enough on the femur. The plate is then provisionally fixed with 1–2 Kirschner wires distally. The fracture is then indirectly reduced with a combination of traction and an appropriate coronal stress. Sagittal alignment is typically influenced by the deforming force of the gastrocnemius causing a posterior moment on the distal fragment. This deformity is typically controlled with a bump or a radiolucent triangle under the

Fig. 3: Anteroposterior (AP) intraoperative view demonstrating placement of the distal femoral locking plate with restoration of length and coronal alignment.

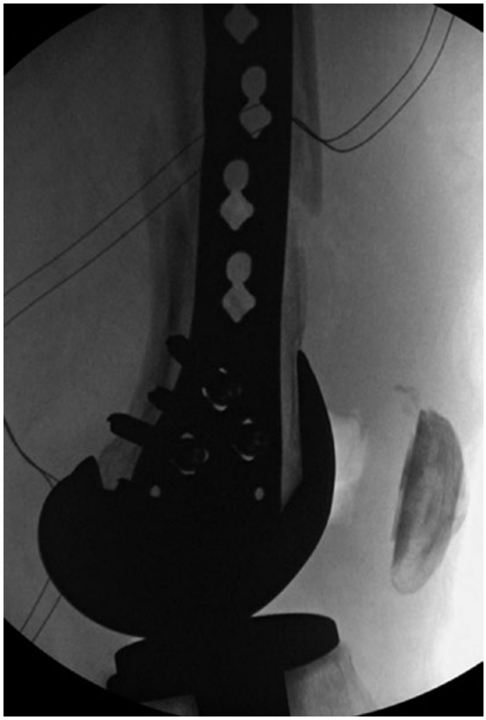

Fig. 4: Lateral intraoperative view demonstrating relative restoration of sagittal alignment.

distal fragment creating an anterior-directed force for appropriate reduction. The anesthesiologist should be instructed to perform complete muscle relaxation while performing these maneuvers to allow ease of reduction. Appropriate length and rotation is confirmed with fluoroscopic imaging. Proximal fixation is then secured with provisional Kirschner wire fixation. Fluoroscopic imaging once again confirms on the anteroposterior and lateral views appropriate placement of the distal femoral locking plate. Minor corrections in the coronal and sagittal planes are still possible prior to placing the cortical and locking screws. Locking screws are then incorporated distally, followed by four (or more pending the fracture pattern) proximal cortical screws in a percutaneous fashion allowing for appropriate bridging of the distal femoral fracture (Figs. 3 and 4).

Postoperative Results

This patient's weight-bearing was limited to toe touch for the first 12 weeks with a hinged knee brace. Her knee brace was locked in extension for the first 2 weeks, and we then increased her range of motion from 0° to 80° with an increase in range of motion 20° weekly as she was able to tolerate. In general weight-bearing status is dictated on fracture reduction and bone quality. Many patients may begin range of motion sooner than this patient, and some patients may begin progressive weight-bearing as early as 6–8 weeks.

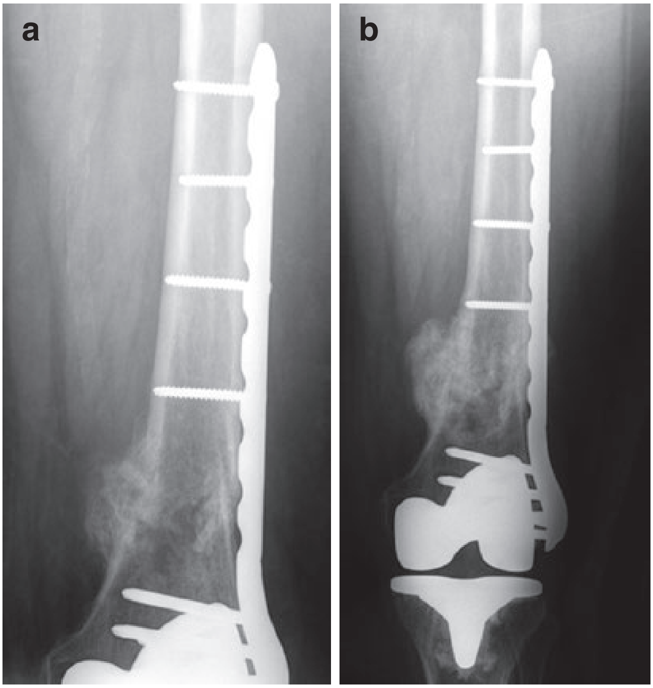

Fig. 5: Anteroposterior (AP) postoperative radiographs showing distal femoral fracture at **(a)** 3 months and **(b)** 6 months with abundant callus formation.

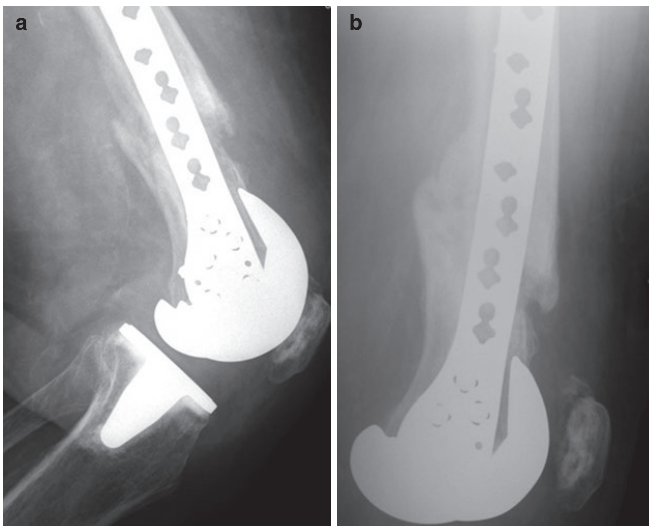

Fig. 6: Lateral postoperative radiographs showing distal femoral fracture at **(a)** 3 months and **(b)** 6 months with abundant callus formation.

The patient's range of motion at last follow-up was 0–115° without pain, and she had returned to her previous preinjury function with her activities of daily living without limitations. Follow-up radiographs show healing of her distal femoral fracture with abundant callus formation at 3 and 6 months postoperatively (Figs. 5 and 6).

Clinical Results

The incidence of periprosthetic fractures after TKA is approximately 2.5% [5]. Supracondylar periprosthetic fracture management is dictated based on fracture location and whether the implant is loose or stable. Previous classification systems have been described [6–9] (Table 1). Fractures around a stable femoral component are typically treated with intramedullary nailing or distal femoral locking plates. For the purpose of this discussion, we will focus on the stable total knee implant with an associated periprosthetic distal femoral fracture.

Intramedullary nailing fixation is advantageous because it limits soft tissue disruption and biomechanically may be superior to locking plating [10]. Some evidence suggest modern intramedullary nail fixation may result in less nonunions/delayed unions [11]. However, most reports consider these rates to be similar between these two types (plate vs. nail) of fixation [12, 13]. Intramedullary nailing cannot be performed in many patients secondary to fracture location and bone stock as well as access issues to the intercondylar notch, particularly in a posterior stabilized design.

The use of an indirect reduction technique with current locking plates as described in the above case is applicable to most patients and prosthetic designs. Locking plates afford the

Table 1: Supracondylar periprosthetic fractures: classification system.

Study	Type/group	Description
Neer *et al*. [8]	Type I	Nondisplaced (<5 mm displacement and/or <5° angulation)
	Type II	Displaced >1 cm
	Type IIa	With lateral femoral shaft displacement
	Type IIb	With medial femoral shaft displacement
	Type III	Displaced and comminuted
DiGioia and Rubash [7]	Group I	Extra-articular, nondisplaced (<5 mm displacement and <5° angulation)
	Group II	Extra-articular, displaced (>5 mm displacement or >5° angulation)
	Group III	Severely displaced (loss of cortical contact) or angulated (>10°); may have intercondylar or T-shaped component
Chen *et al*. [6]	Type I	Nondisplaced (Neer type I)
	Type II	Displaced and/or comminuted (Neer types II and III)
Lewis and Rorabeck [9]	Type I	Nondisplaced fracture; prosthesis intact
	Type II	Displaced fracture; prosthesis intact
	Type III	Displaced or nondisplaced fracture; prosthesis loose or failing

advantage of limited soft tissue stripping over conventional plating in addition to superior biomechanical properties [14]. Locking plate fixation reduces the incidence of overall complications, nonunion, malunion, loss of reduction, and additional surgeries compared with traditional nonlocking plate fixation [15]. Multiple studies have reported reasonable union rates with locked plating for distal femoral periprosthetic fractures [16–19]. Similar to intramedullary nail fixation, locking plates promote early mobilization which may promote clinical healing [19, 20]. Locking compression plates have also been shown to be an effective form of management of distal femoral fractures around long stem TKAs [21].

Most studies show no significant differences in nonunion, revision rates, or clinical outcomes when comparing intramedullary nail vs. locking plate fixation of distal femoral periprosthetic fractures [22, 23]. Ristevski *et al.* [13] showed no significant differences with regard to nonunion rates or rate of secondary surgical procedures in a recent systematic review. There was a significantly higher malunion rate with intramedullary nailing when compared with locked plating; however, the significance of this finding is unknown. Similarly, Li *et al.* [12] in their meta-analysis found no differences in 6-month union rate, union time, or complication rates between the two methods of fixation. In contrast to the above findings, others have reported a potential greater union rate [24] and decrease complication rate [24, 25] with locked plates in certain fracture types. Whereas others have reported intramedullary nail fixation being superior in terms of nonunion and complication rates [11]. One study defined the risk factors specific for failure after locking plate fixation which included open fracture, diabetes, smoking, increased body mass index, and shorter plate length; however, they concluded most factors are out of the surgeon's control [26]. Given the paucity of evidence directly comparing intramedullary nailing and locked plating techniques for periprosthetic fractures of the distal femur, further research is warranted in this area. Regardless of the device chosen, secure distal fragment fixation must be achieved for predictable healing.

Despite significant advances in surgical technique (nail vs. locking plate) and regardless of the fracture type or implant design, the treatment of periprosthetic femur fractures above a TKA remains a challenge. The overall complications in this patient population remain high, including mortality [11, 18, 27, 28], and many patients will continue to experience persistent disability [17, 28–30].

A distal femoral replacement megaprosthesis may be warranted in low-demand patients with a loose implant and/or poor bone stock (Figs. 7 and 8). Recent data suggest that in certain fracture types, a distal femoral replacement may lead to better functional outcomes at 1 year [30]. Lastly, a salvage technique combining intramedullary nailing augmented with bone cement has been described in patients where a standard retrograde nail or plating alone is inadequate in severely osteoporotic bone [31]. This may be reasonable in this patient population; however, the authors of this chapter are unable to comment on this technique since we have not utilized this in this patient population.

Fig. 7: Anteroposterior (AP) view of a distal femoral fracture with significant comminution and loss of bone stock.

Fig. 8: Lateral view of a distal femoral fracture with significant comminution and loss of bone stock.

Key Points

- Implant stability and bone stock will determine the method of fixation.
- A CT scan may be helpful preoperatively to determine the fracture pattern and implant stability
- Most fractures can be treated with internal fixation (locking plate vs. intramedullary nail) utilizing the basic principles of fracture management.
- Minimally invasive techniques have increased union rates and decreased overall complications compared with traditional plating methods.
- Despite these surgical advances, nonunion remains a concern regardless of fixation type, and the overall complication rate in this patient population remains high, including mortality.
- In general, primary distal femoral replacement is reserved for low-demand patients with a loose implant and/or poor bone stock.

Option 2: Distal Femoral Replacement

Aldo M. Riesgo and William L. Griffin

Case Presentation

History

The patient is a 74-year-old female who presented with right knee pain and deformity after a fall from a standing height. She is 12 years status post total knee arthroplasty (TKA) for significant osteoarthritis with valgus deformity performed at an outside institution. At her baseline, she was quite pleased with her clinical result and did not use an assistive device to ambulate. After her fall, the patient was brought to an outside emergency department. She was transferred to our medical center for definitive surgical care.

Physical Examination

Height 5'5", weight 187 lb., body mass index 31.1 kg/m^2. She is nonambulatory currently due to pain from her fall. Her extremity examination reveals significant varus deformity and shortening. Her skin is intact with mild ecchymosis in the thigh with a well-healed midline anterior knee incision. Range of motion testing was deferred, but prior examinations revealed 0–115°. No palpable defect of the extensor mechanism is noted at time of injury. Examination of the leg reveals no other abnormalities. Palpable pulses are noted. Motor and sensory examination is unremarkable.

Radiographs and Advanced Imaging

The primary total knee required a tibial intramedullary stem and a lateral augment for the valgus deformity (Fig. 9). The injury films showed a comminuted periprosthetic distal femoral fracture with minimal bone remaining on the femoral component (Fig. 10).

Surgical Approach

The patient was positioned supine with a standard total knee setup. The prior surgical incision was identified, and full-thickness flaps were made down to the extensor mechanism. In this case, a standard medial parapatellar approach was used leaving a 1-mm cuff of medial quadriceps tendon proximally. The arthrotomy was extended distally to the level of the tibial tubercle. If extension of the arthrotomy is necessary or the exposure is particularly difficult, our preference is to begin with a quadriceps snip. Quadriceps turndowns or tibial tubercle osteotomies are usually unnecessary in this setting of periprosthetic fracture since removal of the distal femur creates significant space.

Fig. 9: Anteroposterior and lateral views of the right knee prior to trauma. Well-fixed hybrid total knee arthroplasty (Vanguard SSK Revision Knee System, Zimmer Biomet, Warsaw IN, USA) with stemmed tibial component. Lateral hemiplateau augment used due to lateral tibial bone loss from severe valgus osteoarthritis. Note the presence of osteolysis behind the femoral component and underneath the tibial baseplate.

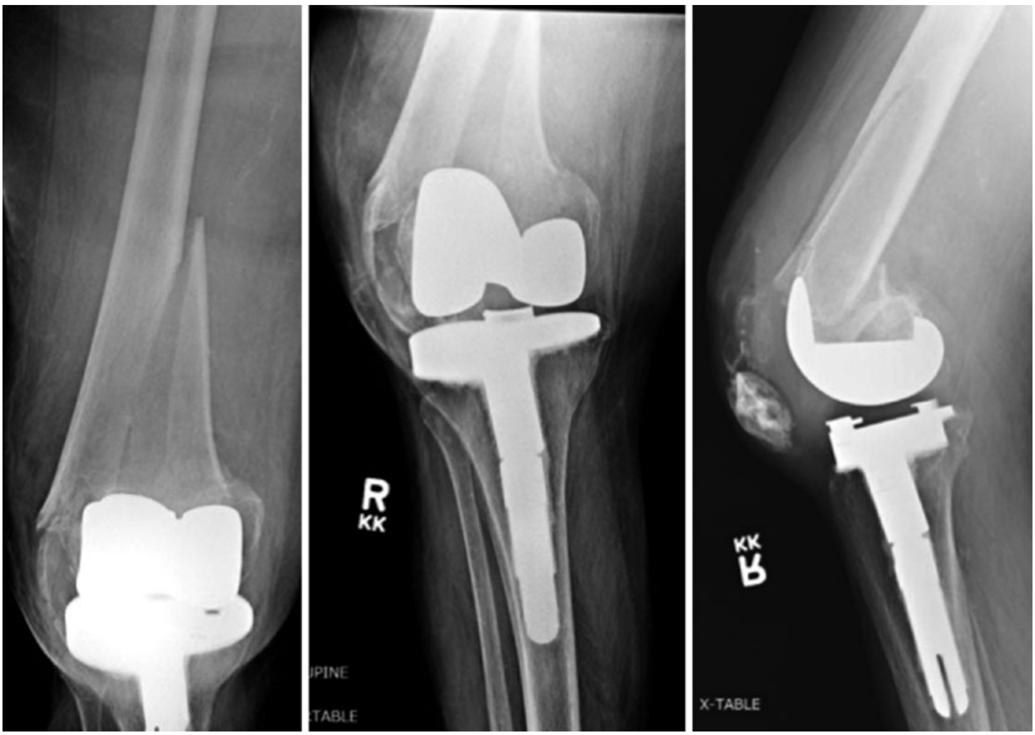

Fig. 10: Anteroposterior and lateral views of the right knee demonstrating a comminuted periprosthetic supracondylar femur fracture. Note the large medial butterfly fragment extending proximally.

Recreation of the medial and lateral gutters is performed. All hypertrophic scar is debrided systematically to the depth of the normal supracondylar fat and underside of the vastus. The superior lateral geniculate vascular bundle is identified, and a partial lateral release is performed with perseveration of the bundle. This allows for improved access to the lateral gutter. The patellar component is inspected for signs of loosening. In this case, it was not revised.

If possible, bony landmarks should be used to try and assess anatomic rotation of the distal femur. Longitudinal traction can be used to help determine appropriate rotation that is then scored on to the remaining distal femur as a guide for implantation. The linea aspera can also be identified and used as a landmark if too much comminution is present. At this point, the collateral ligaments are removed subperiosteally with electrocautery. A small, sharp bone hook is then passed underneath the anterior flange of the femoral component. With an assistant providing gentle anterior traction with the bone hook, the femoral component with attached distal femoral bone is dissected subperiosteally from proximal to distal. All posterior capsule is left undisturbed to protect the neurovascular structures. The femoral component and associated bone is then removed (Fig. 11). The removed segment is measured to plan for appropriate reconstruction with the distal femoral replacement.

The fracture site of the distal femur is exposed and a freshening cut is made. The minimum amount of distal femur is resected to accommodate the distal femoral replacement component. Preservation of metaphyseal bone facilitates the use of cones or sleeves to augment metaphyseal fixation of the final reconstruction. In this case, the large medial butterfly fragment was anatomically

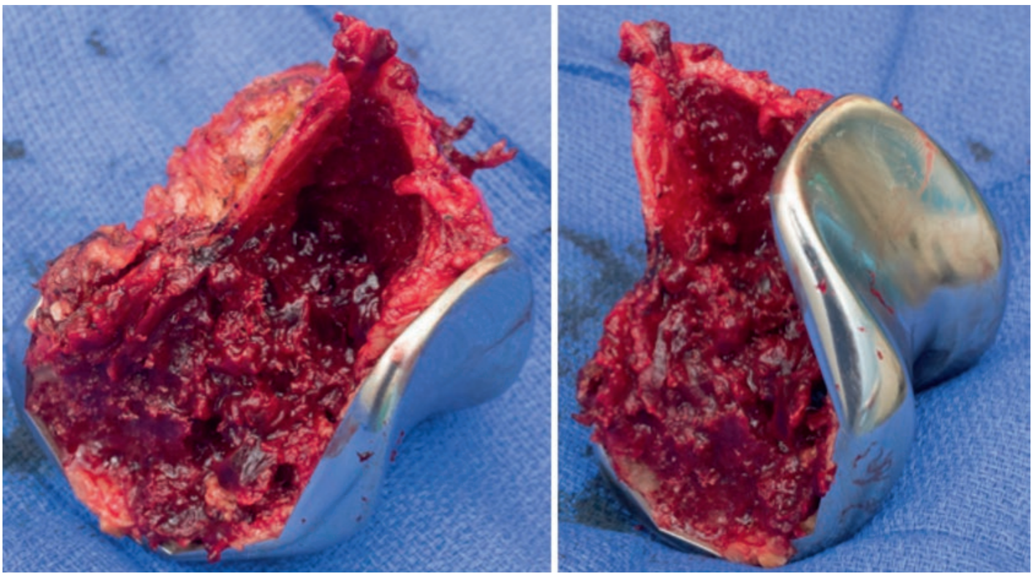

Fig. 11: Intraoperative photo of femoral component with associated bone. Note osteolysis and compromised cortical bone stock prohibiting attempt at internal fixation.

reduced and stabilized with two Luque wires. The Luque wires should be twisted and not cut at this point. The twisted loop can serve as a retractor and elevator of the femoral diaphysis, providing control of the femur during further preparation.

Attention was then turned to the tibia. It was translated forward and retractors were placed laterally. The implant-bone interface was identified, and the tibial component was removed with a combination of micro-sagittal and reciprocating saw blades and osteotomes. To expose the lateral augment, a release of the lateral capsule off the anterolateral tibia was performed with careful retraction of the patellar tendon.

There was significant osteolysis beneath the tibial baseplate. Despite meticulous technique during removal, there was a considerable amount of lateral tibial bone loss after component removal. The proximal tibia was then prepared for an asymmetric tibial cone. Our preference is to use cemented stems that can be shorter and do not need to fully engage the diaphysis, especially when metaphyseal fixation cones are used.

On the femur, a long diaphyseal engaging stem is used to sufficiently bypass the medial fracture. There was insufficient femoral metaphysis to accept a metaphyseal cone. The intramedullary canals were sized and reamed to only 2 mm larger than final implant. This preserves as much cancellous bone as possible to allow for cement interdigitation. Appropriately sized trials were inserted, and an intraoperative radiograph was obtained to confirm alignment and sizing and assess for iatrogenic fractures during implant removal. At this point, femoral rotation is set. Setting appropriate external rotation is difficult whenever the epicondyles and collateral ligaments are absent. If an appropriately rotated implant is present, scoring the anterior cortex prior to implant removal helps determine appropriate rotation during implantation. This can be difficult to assess in the periprosthetic fracture setting, however. The linea aspera can also be identified and used as a landmark to confirm appropriate rotation. With the trials in place, an additional 3–5° of external rotation can usually be incorporated. Patellofemoral dislocation is a common cause of failure in distal femoral replacements. In our experience, there is little downside to additional external implant rotation in a hinged device, but significant downside to poor patellofemoral tracking. All trials were removed, and after preparing the bone for cementation, the implants were cemented into appropriate position.

Postoperative Result

The patient was made weight-bearing as tolerated immediately postoperative. She progressed well and at 3 months had regained all abilities for activities of daily living with a walking tolerance of 1 mile. Knee range of motion is 0–110° (Fig. 12).

Clinical Results

Distal femur fractures are the most common periprosthetic fractures following TKA [1]. While the optimal treatment of periprosthetic distal femur fractures remains controversial, appropriate

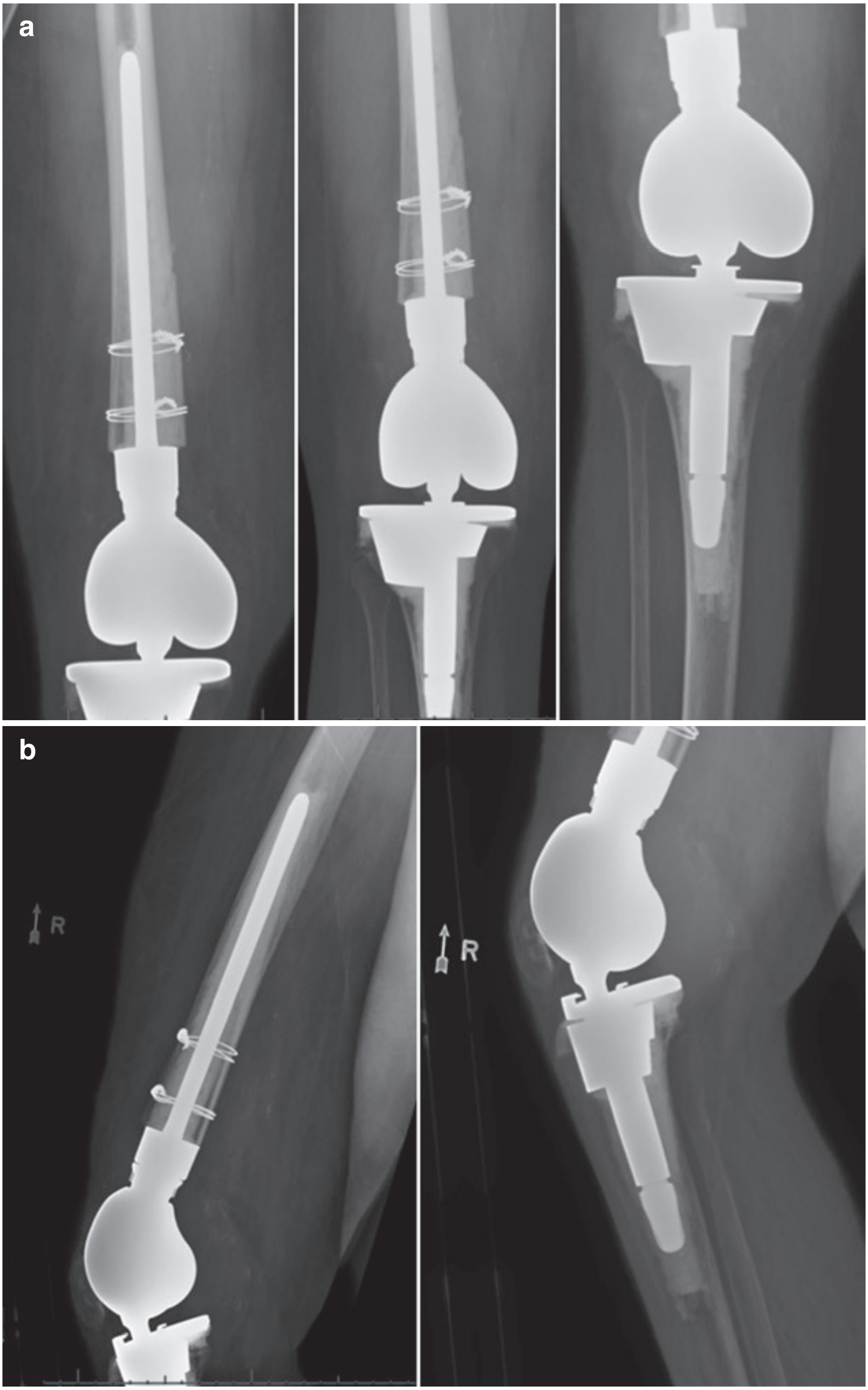

Fig. 12: (**a, b**) X-rays taken 3 months postoperatively show well-fixed cemented implants (Zimmer Segmental System distal femoral replacement with trabecular metal tibial cone, Zimmer Biomet, Warsaw IN, USA).

stability with standard internal fixation is difficult to obtain in very distal fractures with associated osteopenia and osteolysis [17]. When there is inadequate bone for distal fixation, distal femoral replacement is an attractive option in patients with poor bone stock [32, 33]. Some authors have suggested that revision arthroplasty offers improved chance of both survival and avoidance of reoperation in the setting of periprosthetic fractures [34–36].

There are few published series assessing distal femoral replacement for the management of supracondylar periprosthetic fractures. While the overall failure rate is low and short-term patient outcomes are improved compared to internal fixation, there is a substantial complication rate (up to 33%) associated with distal femoral replacement for periprosthetic fractures [4, 37].

In a review of 291 periprosthetic fractures from our institution, we found 13% mortality and 12% revision rates in all periprosthetic fractures at 1 year. The risk of reoperation and survival is improved in distal femoral replacements when compared to those patients treated with open reduction and internal fixation [36].

In an elderly population, high nonunion and fixation failure rates have been reported following open reduction internal fixation (ORIF) of distal femur periprosthetic fractures [38]. In a recent study from our institution looking at distal femur fractures without a prosthesis, 20% of patients older than 70 years developed a nonunion after ORIF of an intra-articular distal femur fracture. At 1-year follow-up, all patients in distal femoral replacement (DFR) group were ambulatory, while one in four in the ORIF group was wheelchair bound [2]. While this cohort did not include periprosthetic fractures, it does highlight the potential downside of internal fixation in the elderly. The short-term results of DFR appear to be durable. A recent study with an average 4-year follow-up demonstrated that the functional scores (Harris Hip Score, Oxford Hip Score, Funktionsfragebogen Hannover, and SF-36 Questionnaire) of DFR patients were slightly higher, and their visual analog scale (VAS) scores were significantly lower than the scores of the patients after ORIF [39]. Long-term results and substantial follow-up, however, are limited in this elderly population.

With high reported loosening rates with cemented megaprosthesis [40], our preferred technique to is to use supplemental metaphyseal fixation and short cemented stems that do not fully engage the diaphysis. Cementing into metadiaphyseal bone allows for better interdigitation and fixation than cementing into diaphyseal bone. There is substantial literature to support the use of metaphyseal cones or sleeves in the revision TKA setting [41–43]. Whenever possible, cones or sleeves should be used in combination with DFR. In elderly osteoporotic patients, cementless fixation should be avoided.

Key Points

- Medial parapatellar arthrotomy is preferred exposure.
- Extensile exposures are usually unnecessary.
- Mark rotation of femoral component on anterior cortex of femur prior to removal if possible. Linea aspera can be used for reference. If not, use trials and add additional external rotation.

- Must measure removed femoral component, fracture site, and planned "freshening" osteotomy to ensure that sufficient resection has been made for each corresponding implant (e.g., Zimmer Segmental requires 90 mm resection).
- Removal of components should be meticulous and systematic using thin saw blades and osteotomes. Avoid unnecessary bone loss in osteoporotic patients.
- Use Luque wire around remaining femur for prophylaxis against fracture propagation and to provide control of femur during preparation.
- Low threshold to perform lateral release if patellar maltracking is noted.
- Patella should be inspected and rarely needs to be revised.
- Supplemental metaphyseal fixation with cones/sleeves is encouraged.
- Longer stems should be used when bypassing fractures.
- Avoid cementless fixation in elderly osteoporotic bone.

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Total Knee Arthroplasty in Patients with Prior Ipsilateral Hip Arthrodesis

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Abstract

Only a few articles based on the management of symptomatic knee osteoarthritis in patients with prior ipsilateral hip arthrodesis have been reported, and there are no clear criteria for the best treatment option [to carry out a total knee arthroplasty (TKA)—or to take down the hip fusion and conversion to a total hip arthroplasty—THA, and after that to carry out the TKA]. We report two cases, a 72-year-old male who underwent a left hip arthrodesis at 28 because of a trauma and a 51-year-old woman who underwent a left hip arthrodesis at 9 years because of a congenital dislocation. They presented severe ipsilateral symptomatic knee osteoarthritis. Once the cases were studied and the two therapeutic possibilities were evaluated, we decided to perform TKA. Currently, both patients have no pain, a stable knee with good range of motion and without aseptic loosening radiologic criteria.

Keywords: Hip arthrodesis, Knee osteoarthritis, Total knee arthroplasty, Total hip arthroplasty

Introduction

Patient's knees with hip arthrodesis are subject to different motion patterns than normal knees [1]. No motion at the hip is compensated with increased transverse and sagittal rotation of the pelvis, increased motion of the contralateral hip, and increased flexion of the ipsilateral knee throughout the stance phase of gait in which weight is borne on the fused side.

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In consequence, long-standing hip arthrodesis often causes pain, functional impairment and degeneration in neighbouring joints [2–5]. The incidence of degenerative changes in the ipsilateral knee after hip arthrodesis is greater than 68% [2, 6].

There are few articles setting out which is the best therapeutic option. It can simply be done a TKA. Authors advise that the arthrodesed hip should be in good position to minimize the risk of premature wastage and loosening. The other option is to take down the hip fusion into a THA (high complexity and risk of complications surgery) and perform TKA in a second time. The advantage of this option is the realignment of the mechanical axis and therefore less risk of premature wastage and loosening of the implant in the knee.

Our goal is to present our experience with two cases and perform a literature review of the topic.

Case Reports

Case 1

A seventy-two-year-old male underwent a left hip arthrodesis at the age of 28 because of a trauma. The fused hip was with 5° of flexion, 5° of adduction and 0° of external rotation (Fig. 1).

The patient developed ipsilateral symptomatic knee osteoarthritis so we decided to carry out surgical treatment by PS-TKA (NEX-GEN).

It has been 11 years after surgery, and the patient has no pain, a stable knee with a range of motion of 0°–90° and without aseptic loosening radiologic criteria.

During this time, he has no complications and can carry out his daily life activities without problems (he has improved from 49 preoperative points to 65 actual points in the KSS and from 38 to 68 in the WOMAC score).

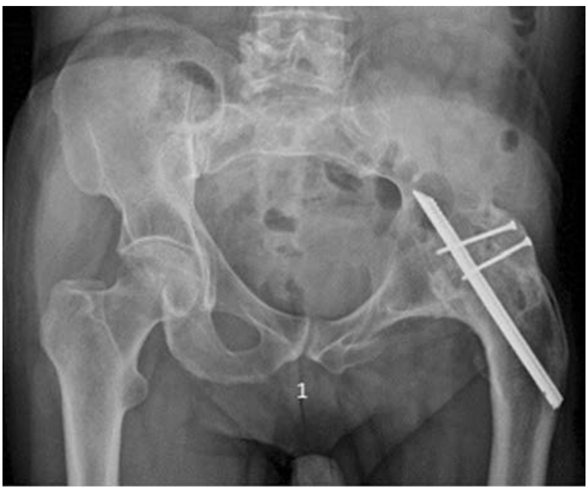

Fig. 1: Case 1: A 72-year-old patient with left hip arthrodesis.

Case 2

A fifty-one-year-old female underwent a left hip arthrodesis at 9 years because of a congenital dislocation. The patient also presented an equine and cavus foot, and the hip fused was with 10° of flexion, 5° of abduction and 5° or external rotation and a lower limb discrepancy of 5.1 cm. In order to be able to walk, the patient had to force valgus of the knee, because otherwise the position of the foot made for her impossible to walk.

She presented a severe 40° genu valgus and scoliosis; however, she did not refer any back pain. Given her age at that time (17), we decided to perform a tibia varus osteotomy (synthesized stapled). Afterwards, at the age of 28 the patient underwent a supracondylar varus osteotomy (synthesized with 90° angled plate). The patient developed severe ipsilateral symptomatic knee osteoarthritis (Fig. 2A). A preoperative pelvic MRI showed an important soft tissue atrophy (Fig. 3). Our electromyogram showed absence of voluntary muscle activity in the gluteus maximus, gluteus medius and gluteus minimus muscles.

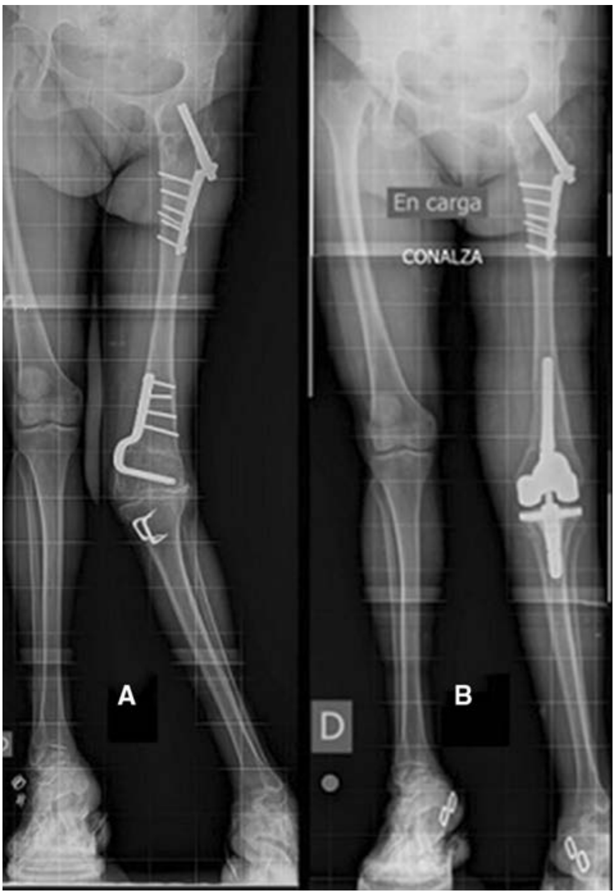

Fig. 2: Case 2: Full-length standing lower limb radiograph showing a valgus alignment and post-operative control.

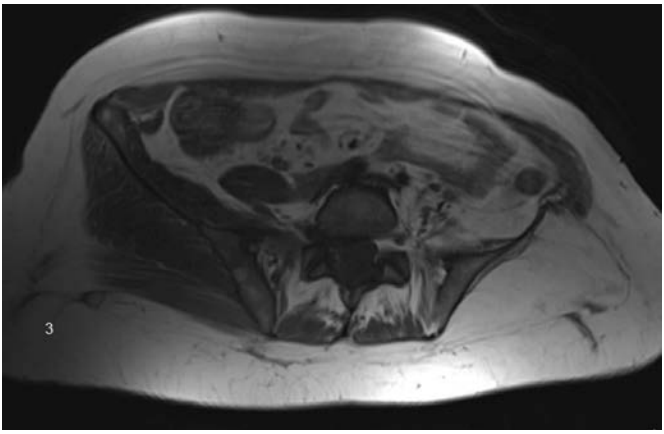

Fig. 3: Preoperative MRI showing a severe soft tissue atrophy.

Thus, after considering the two surgical options—TKA versus takedown arthrodesis plus THA and TKA—we opted for osteosynthesis material extraction and placement of a TKA. Since our patient had a severe valgus deformity with incompetent medial collateral ligament and physical examination revealed valgus laxity greater than 5 mm in full extension, a semi-constrained implant was considered the best implant for knee replacement (TKA LCCK with femoral and tibial stem) (Fig. 2B).

One year after surgery, she has no complications, no pain, significant improvement in gait pattern, with a mechanical axis of 5°, a stable knee with a similar range of motion as the preoperative (0°–70°), and without aseptic loosening radiologic criteria.

She is able to carry out her daily life activities without problems (she has improved from 13 preoperative points to 88 actual points in the KSS and from 40 to 59 in the WOMAC score).

Discussion

To the best of our knowledge, only three case reviews and two technical notes address the issue of TKA surgery in patients with previous hip arthrodesis.

This is a retrospectively review [7] (7-year mean follow-up) with 9 patients in whom arthrodesis (in an appropriate position) is maintained and who underwent a TKA. Their results are comparable to patients who underwent TKA without hip arthrodesis. They observed an increase incidence of post-operative stiffness (7 patients, 3 of whom required more than one manipulation under anaesthesia), which we did not observe in our two patients.

The second study [6] reviews 16 hip arthrodeses that develop ipsilateral gonarthrosis, performing in 4 of them TKA and in the others 12 takedown of the hip fusion and THA, followed by a second-stage TKA. The results are very good in both groups with very few complications (the first group increases the HSS knee score from 43.5 to 72.1 and the second one from 28 to 72.5 with a mean follow-up of 5.5 years). Authors reported that both treatment options may provide good results. However, they support a hip fusion takedown since from their point of view the hip arthrodesis needs to be in good position to allow good results of the TKA. Regretfully, the authors do not provide any data to support this approach.

Rittmeister *et al.* [8] review 18 patients with hip arthrodesis and ipsilateral gonarthrosis, with a 33-year mean follow-up. 11 patients underwent only a THA, 4 patients underwent takedown of the hip fusion and THA, and in second time TKA, and 3 underwent a TKA only. According to the results obtained (the second group had an improvement in the HSS knee score from 33 to 78, while the third group from 35 to 44), they suggest that carrying out only the TKA is not enough to achieve a satisfactory result (especially if the hip is fused in an inadequate position) and that it is preferable to carry out the THA first and then the TKA.

The other two articles [9, 10] explain technical tips to carry out the TKA in these patients. The first one [9] is a technical article that shows intraoperative modifications to facilitate surgery. In the second one [10], they comment based on previous studies [7, 8] that the position of the hip arthrodesis is important when deciding the type of surgical intervention. Two cases are presented of hip arthrodesis in an appropriate position (15°–30° of flexion, 5°–10° of adduction and 0°–10° of external rotation) in which they perform TKA with good long-term results. In one of them, the preoperative study MRI showed atrophy of soft tissues. According to the authors, in this case the option of takedown of the hip fusion and THA is not a safe option. Therefore, they maintain that in many cases (due to the high complications rate), performing THA prior to TKA would may not be the best option.

The hip fusion in patient two was not in optimal position (being this 15°–30° of hip flexion, 5°–10° of adduction and 0°–10° external rotation) [10]. The hip position was evaluated clinically by a senior hip surgeon.

In this patient, we faced two problems at the time when surgical decision had to be made. Firstly, due to the important atrophy of soft tissues presented, we were aware of the potential complications of a hip fusion takedown and THA. Secondly, as the patient presented an equino-cavus foot, when balancing the hip, we would also have to correct the foot abnormalities before the TKA (the abnormal position of the foot is adapted to the inappropriate position of the arthrodesis so if we correct the arthrodesis, we would also have to correct the abnormal position of the foot in order to adapt it to the new gait pattern).

Although electromyography showed absence of voluntary muscle activity in the gluteus maximus, gluteus medius and gluteus minimus muscles, we must bear in mind that most investigators have not found any association between the intraoperative findings and the results of electromyography. It has been established that the best predictor factor for walking ability in patients after THA following hip fusion is the status of the gluteal muscles. However, the state of the gluteal muscles seems to be unpredictable preoperatively before conversion. Our patient did not complain of low back pain which we believe to be the main indication for reconversion into THA.

Thus, consensually with the patient, despite the fact that the hip was not in an adequate position, we preferred to perform a TKA with the idea of performing the takedown of the hip fusion and THA in a second time if necessary.

Conclusion

Our results and the literature review suggest that performing TKA in patients with symptomatic severe gonarthrosis after hip arthrodesis is a good short- and long-term option with fewer complications than takedown of the hip fusion and to carry out a THA and in a second time the TKA. When patients complain of lower back pain associated with severe degenerative changes THA should be considered.

The position of the hip should be appropriate for every patient, and it is essential to individualize and study what is the best therapeutic option in every case.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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