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Do radiographic and functional results correlate after fixation of Schatzker V-VI tibial plateau fractures?

Schatzker V-VI tibial plato kırıklarının fiksasyonundan sonra radyografik ve klinik sonuçlar arasındaki korelasyon

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Objectives: High-energy tibial plateau fractures are complex injuries that have varying outcomes. Our purpose was to evaluate outcomes of operatively treated Schatzker type V and VI tibial plateau fractures and compare them to the radiographic results.

Patients and methods: Eighty consecutive patients underwent operative treatment for Schatzker type V (21 fractures) or type VI (62 fractures) tibial plateau fractures. There were 64 closed (77.1%) and 19 open fractures (22.9%), with 11 extremities (13.3%) having compartment syndrome. Fifteen patients (18.8%) with 18 fractures were lost to follow-up. Finally, 65 patients with 65 extremities were available for clinical and radiographic examinations after a mean follow-up of 17 months (range 10 to 40 months). Functional assessments were made using the WOMAC (Western Ontario and McMaster Universities Arthritis Index) questionnaire.

Results: The mean range of knee motion at the latest follow-up was 1° (0° to 20°) - 115° (60° to 140°) and the mean WOMAC score was 76.6±55. Radiographically, 15 knees (23.1%) had evidence for collapse and 11 patients (16.9%) had evidence for post-traumatic arthritis. Both loss of fracture reduction (p=0.001) and arthritic changes (p=0.04) were associated with a poorer functional score on the WOMAC. Complications included five deep wound infections (7.7%), two nonunions (3.1%), and 10 patients required additional unplanned surgery (15.4%).

Conclusion: Early loss of surgical reduction and development of radiographic evidence for arthritic changes are predictors of functional scores in Schatzker type V and VI tibial plateau fractures.

Key words: External fixators; fracture fixation, internal; knee injuries/surgery; postoperative complications; tibial fractures/classification/surgery/radiography; treatment outcome.

Amaç: Yüksek enerjili travmayla oluşan tibial plato kırıkları tedavisi zor yaralanmalardır ve sonuçları değişkenlik göstermektedir. Bu çalışmada, Schatzker tip V-VI tibial plato kırıklarının cerrahi tedavi sonuçları değerlendirildi ve radyografik sonuçlarla karşılaştırıldı.

Hastalar ve yöntemler: Çalışmada Schatzker tip V (21 kırık) ve tip VI (62 kırık) tibial plato kırığı olan 80 ardışık hasta geriye dönük olarak incelendi. Kırıkların 64'ü kapalı (%77.1), 19'u açık (%22.9) kırık idi. On bir ekstremitede (%13.3) kompartman sendromu vardı. On sekiz kırıklı 15 hasta (%18.8) takipten çıktığından, klinik ve radyografik incelemeler 65 hastanın 65 kırığı üzerinden yapıldı. Ortalama takip süresi 17 ay (dağılım 10-40 ay) idi. Fonksiyonel değerlendirme WOMAC (Western Ontario and McMaster Universities Arthritis Index) anketi kullanılarak yapıldı.

Bulgular: Son takipte ortalama diz hareket açıklığı 1° (0°-20°)-115° (60°-140°), ortalama WOMAC skoru 76.6±55 bulundu. Radyografik olarak 15 dizde (%23.1) çökme, 11 hastada (%19.6) posttravmatik artrit bulguları saptandı. Redüksiyon kaybı (p=0.001) ve artritik değişiklikler (p=0.04) WOMAC değerlendirmesinde daha kötü skorla ilişkili bulundu. Komplikasyon olarak, beş hastada derin yara enfeksiyonu (%7.7), iki hastada kaynamama (%3.1), 10 hastada planlı olmayan ek cerrahi girişim (%15.4) görüldü.

Sonuç: Erken cerrahi redüksiyon kaybı ve radyografik olarak artritik değişikliklerin gelişimi Schatzker tip V-VI tibial plato kırıklarında fonksiyonel skorlar için öngördürücü olmaktadır.

Anahtar sözcükler: Eksternal fiksatör; kırık tespiti, internal; diz yaralanması/cerrahi; ameliyat sonrası komplikasyon; tibia kırığı/sınıflandırma/cerrahi/radyografi; tedavi sonucu.

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Historically, attempts at acute open reduction and internal fixation of high-energy tibial plateau fractures have been associated with high rates of wound complications.[1-5] According to Watson,[4] there are four factors of the fracture personality that determine prognosis in high-energy proximal tibia fractures. These include the degree of articular step off, the extent and separation of condylar fracture lines, meta-diaphyseal dissociation, and the integrity of the soft tissue envelope. Therefore, the energy imparted to the extremity via the mechanism of injury and its resultant fracture pattern are somewhat a signal to the treating physician for the presence of a more significant injury with a worse prognosis.

Excluding the elderly population, high-velocity trauma is the major mechanism involved in Schatzker type V and VI tibial plateau fractures. Resulting in concomitant soft tissue damage and joint instability, these injuries presents a challenging task for the treating physician. Among published literature, operative planning for these injuries includes specific surgical techniques, but with varying descriptions of final outcomes. Current objectives of surgical intervention for complex tibial plateau fractures involve restoration of the articular surface and preservation of joint function. Recent measures to minimize soft tissue disruption on initial presentation and exploring particular modalities for definitive management emerged as crucial steps in management of these injuries.[1,6-10] However, results of management of these complex injuries are not well described in today's literature.

The purpose of this study was to evaluate the objective functional and radiographic outcomes following the operative treatment of Schatzker type V and VI tibial plateau fractures.

PATIENTS AND METHODS

After obtaining institutional review board approval, we identified 80 consecutive patients with 83 fractures, who underwent operative treatment for Schatzker type V (21 fractures) or type VI (62 fractures) tibial plateau fractures in the trauma database of our hospital system.

Fig. 1. A 40-year-old male involved in a motorcycle accident. **(a)** Injury AP demonstrates a comminuted Schatzker VI plateau fracture. **(b)** Application of a knee spanning external fixator allows for reduction of the fracture and limb alignment. **(c)** The spanning frame.

Operative logs, hospital and office charts were reviewed to determine general demographics, mechanism of injury, associated injuries, operative procedures, and follow-up course of these patients. Fractures were classified according to the OTA classification[11] and the Schatzker classification of tibial plateau fractures.[12] Open fractures were classified according to the Gustilo-Anderson system.[13] There were 35 associated injuries in 27 patients (33.8%).

Patients with open fractures had their wounds irrigated and debrided with nine liters of jet lavage saline with primary closure over drains if possible, followed by application of a four-pin knee spanning external fixator (Fig. 1a- c).[14] Three patients had percutaneous screw placement across nondisplaced articular fractures involving the knee joint at the same time as the external fixator placement (Fig. 2). Patients who sustained a compartment syndrome (11 patients with 11 extremities) underwent four-compartment fasciotomy and spanning external fixator placement followed by serial irrigation and debridement until definitive closure of the soft tissue envelope either by delayed closure, split-thickness skin graft, or muscle flap.

To aid in classification and surgical planning, a computed tomography (CT) scan was obtained prior to definitive fracture fixation in all cases except for those receiving a spanning fixator in whom the CT scan was obtained after external fixator application (Fig. 3). The timing and implant choice for definitive fixation was determined by the treating surgeon. Once the patients were determined to be ready for surgery, further treatment of

Fig. 2. Example of percutaneous screw placement across a nondisplaced intra-articular fracture after fixator placement.

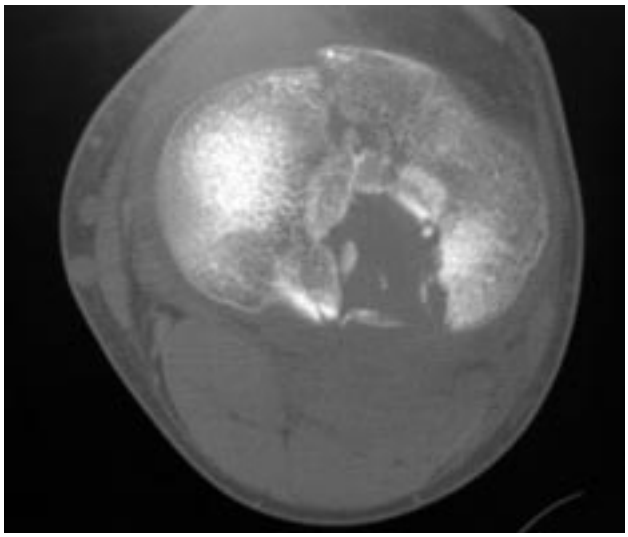

Fig. 3. A computed tomography scan delineates fracture impaction.

osseous injuries was undertaken. The readiness of the soft tissue envelope was somewhat subjective and determined by resolution of swelling marked by the return of skin wrinkles, reepithelialization of fracture blisters, and reduction of edema. Definitive stabilization included restoration of articular congruity using small and mini-fragment screw fixation and meta-diaphyseal fracture repair with either plates and screw constructs or conversion to a thin wire ring fixator at the surgeons' discretion. All patients were treated by one of four fellowship trained trauma surgeons (experience 4-15 years). Thromboprophylaxis was used in the form of low molecular weight heparin from 12 hours postoperatively until discharge and was discontinued 12 hours prior to any surgical intervention. Prophylactic antibiotics were administered prior to, and for 48 hours following any surgical intervention.

Definitive fixation included unilateral locked plating (L.I.S.S., Synthes, Paoli, Pa,) in 47 fractures, dual unlocked plating through two separate incisions in 17 fractures (Fig. 4a-e), unlocked unilateral plating in 11 fractures, and wire fixator (Ilizarov, Spatial frame, Smith and Nephew, Memphis, TN or hybrid fixator, EBI, Parsippany, NJ) in seven fractures. One patient with bilateral injuries underwent an above knee amputation on one side prior to definitive fixation.

The knees were kept immobile for two-three days postoperatively, followed by active and passive range of knee motion with isometric quadriceps strengthening. Patients were kept non-weightbearing for a minimum of 10 to 12 weeks. All patients with closed injuries received intra-

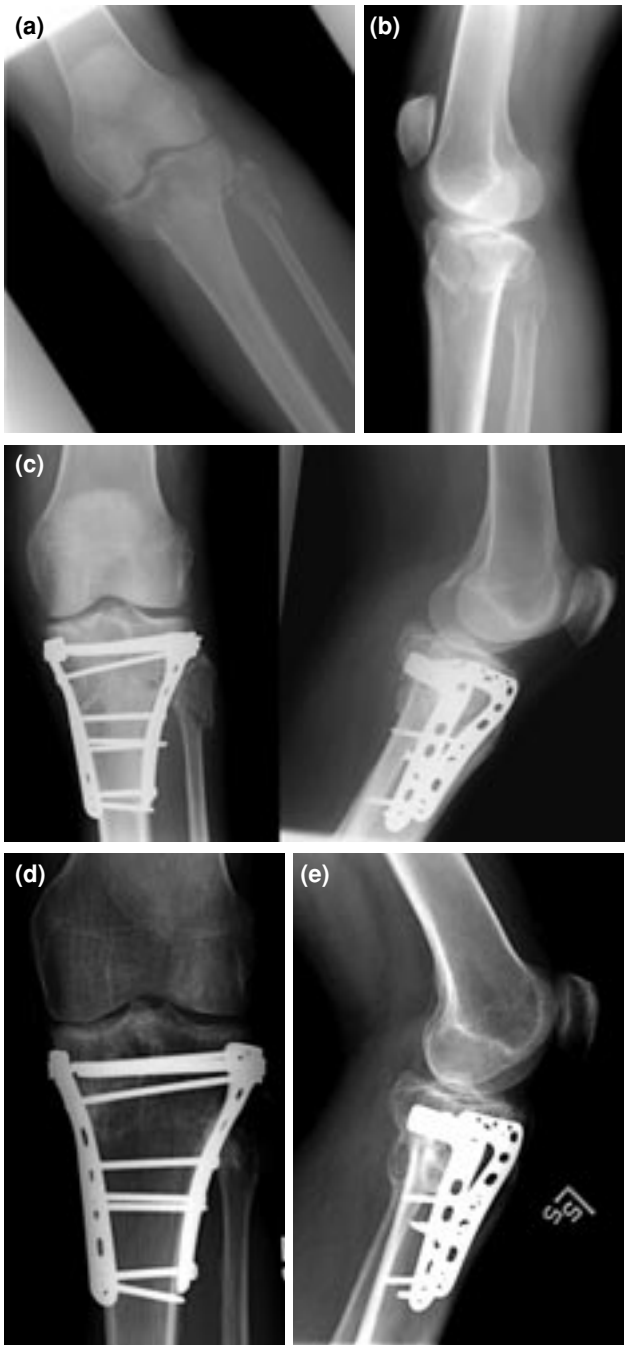

Fig. 4. A 56-year-old female who was struck by a motor vehicle and sustained an injury to her left knee. **(a, b)** A Schatzker V tibial plateau fracture on injury AP and lateral radiographs. **(c)** An excellent reduction is observed on immediate postoperative films. **(d, e)** Radiographs at postoperative 14 months showing a healed fracture with early degenerative changes within the medial compartment.

venous antibiotics for a period of 24 hours after each surgery. Patients with open fractures received 48 hours of double antibiotic coverage consisting of a cephalosporin and aminoglycoside, followed by 24 hours of antibiotics after each visit to the operating room. Patients who developed a deep wound infection were placed on intravenous antibiotics for six weeks.

Patients were examined by their treating physician. Physical examination included knee range of motion and manual muscle strength testing. Functional assessment was obtained by a trained interviewer using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) questionnaire.[15,16] Standard anteroposterior, lateral, and "plateau view" radiographs were obtained for all patients at the latest follow-up. These radiographs were compared to the injury and immediate postoperative films and graded by the authors (KAE, NCT). Films were compared and assessed for adequacy of articular reduction and maintenance of that reduction as well as the presence of post-traumatic arthritis (graded mild, moderate, or severe). Articular depression was measured on the plateau view radiograph by measuring the distance from a horizontal line drawn from maximum depression to a line drawn parallel to opposite intact articular surface. If both the medial and lateral articular surfaces were involved, a horizontal line was drawn at the level of the base of the tibial spine and another line drawn at the level of maximum depression of both plateaus. The distance between these two lines was recorded as the degree of articular depression.[17]

Statistical analysis

Demographic, injury, operative and postoperative data were expressed as the mean and associated population standard deviation. In order to examine the relationship between radiographic and functional result, subset analysis was performed using the Student's t-test to compare population means. The level of statistical significance was defined as a p value less than 0.05.

RESULTS

Fifteen patients (18.8%) with 18 fractures were lost to follow-up, which included 13 patients (14 fractures) who could not be contacted, two patients (3 fractures) who transferred care prior to definitive fixation, and one patient who had bilateral injuries and had one side amputated prior to definitive fixation. Therefore, 65 patients with 65 extremities were available for final functional follow-up. The mean age of this cohort was 49 years (range 18 to 80 years). The mean length of follow-up was 17 months (range 12 to 40 months). We compared the demographics between those who had sustained a Schatzker type V and type VI fracture and found no significant differences except that all 11 patients with compartment syndromes had sustained a Schatzker VI fracture. Nineteen fractures (22.9%) were open. There were 13 grade IIIA, four IIIB, and two IIIC wounds.

Radiographically, all fractures united at the latest follow-up. There were two patients who underwent planned bone grafting at three months for prophylactic treatment of an impending nonunion due to bone loss at initial injury. Fifteen plateaus (23.1%) had some collapse of the lateral tibial plateau when compared to initial postreduction films, and 11 patients (16.9%) had evidence for post-traumatic arthrosis at the latest follow-up. This association between tibial plateau collapse and post-traumatic arthrosis was significant ($p<0.01$).

Clinically, the mean knee range of motion was 1° (0° to 20°) - 115° (60° to 140°) and the mean WOMAC score for the cohort was 76.6 (STD 55). A WOMAC score of more than one standard deviation above the mean was considered to be a poor functional result. There was a strong association between the loss of postoperative reduction ($p=0.001$) as well as development of arthritic change ($p=0.04$) and scoring more than 1 standard deviation above the mean on the WOMAC. Patient demographics, fracture type, or associated soft tissue injuries were not correlated with a poorer functional result.

Complications

There were five deep infections, all of which were treated with irrigation and debridement and long-term antibiotics. Two of these patients required removal of hardware after presumed bony union, and one was converted to a ring fixator because of failure to control infection with internal fixation in place. One infection was successfully suppressed with intravenous antibiotics alone. There were two infected nonunions. The patient who transferred care was successfully treated with a multi-axial external fixator (considered in the lost to follow-up group, although outcome is known). One patient

required conversion to a total knee replacement after debridement and eradication of infection. Another two patients had impending nonunions as described earlier, who underwent prophylactic bone grafting at three months. There were five patients with painful hardware, who underwent removal of hardware and arthroscopy. Two patients developed substantial knee stiffness (<90°), one of which had heterotopic bone formation in the quadriceps in the area of an external fixation pin site. No treatment was sought at the patient's request. The other patient underwent arthroscopic lysis of adhesions and manipulation under anesthesia for limited range of knee motion, which did improve the final arc of knee motion past 100° of flexion.

DISCUSSION

In this series, we report our experience with high-energy tibial plateau fractures with associated soft tissue compromise. We utilized various soft tissue-friendly approaches and techniques. These included the use of knee joint spanning external fixation to temporize patients with compromised soft tissue envelopes,[7,14] limited or dual incision surgical approaches, and implants that allow for a more biological fracture healing. Overall, we had an incidence of infection or wound problem of 7.7%. This rate compares favorably with historical controls. Many previous articles did not break down their complications into fracture type, reporting on all types of tibial plateau fractures.[12,18-21] Furthermore, we utilized an objective functional outcome measure to compare to more recent literature.[15,16]

Various authors have advocated different methods of treatment for these complex injuries. These include open reduction and internal fixation with plates and screws,[1,2,12,18,19,21-25] limited open reduction with percutaneous screw placement or indirect reduction, and application of either a hybrid[25-33] or circular external fixation device.[34] The benefits of open reduction of these injuries include direct exposure and accurate reduction of the articular surface, repair of meniscal and ligamentous injuries, and stable fixation to allow for early range of knee motion. These benefits must be weighed against the risks of wound complications due to surgical insult upon an already compromised soft tissue envelope. The concept of temporary joint spanning external fixation has developed over the last ten years to accomplish restoration of the mechanical and anatomic axes of the tibia and minimize soft tissue complications.[7,14]

Complications have been seen in high-energy proximal tibia fractures regardless of definitive stabilization. Mikulak et al.[29] reported a series of 24 high-energy Schatzker VI tibial plateau fractures treated with thin wire circular fixators with or without limited internal fixation. Complications included two peroneal nerve palsies, two late deep hardware related infections that required revision surgery, seven superficial pin tract infections, one septic arthrosis with resultant osteomyelitis, and one knee flexion contracture.

Stamer et al.[30] reported a series of 23 Schatzker VI tibial plateau fractures in 22 patients treated with hybrid external fixation with or without limited internal fixation. The authors reported mean clinical and functional knee rating scores in the good category. Complications included one pin tract infection, three deep infections (13%), and one malunion.

Moore et al.[2] described dual plating for the treatment of bicondylar tibial plateau fractures. The authors performed a surgery through a single "Mercedes incision" advocated by the AO group at the time. They reported a 23% incidence of deep wound infection and a 25% (14/57) incidence of superficial infection. The authors did not document time from injury to surgery; however, they did report a concern about the condition and volume of the soft tissue envelope as being compromised at the time of surgery.[2]

Young and Barrack[5] reported an 88% deep infection rate in a series of dual platings for complex bicondylar tibial plateau fractures. Because seven of eight patients who had undergone dual plating developed deep infections compared to none who had unilateral plating, they concluded that the double plating had been responsible for their complications. These high incidences of wound complications were perhaps related to failure to recognize soft tissue damage and to an acute surgical intervention through a soft tissue envelope not yet ready to accept a second insult.[5]

Covall et al.[35] treated 32 bicondylar tibial plateau fractures over a seven-year period. They reported a 42% deep infection rate in those treated

with acute internal fixation. Initially, the authors performed open reduction and internal fixation in all of these injuries; however, after an unacceptably high complication rate in the first seven patients they abandoned this approach in favor of less invasive methods. They then began utilizing hybrid external fixation with or without limited internal fixation and arthroscopically assisted surgeries. High-energy tibia fractures, both intra-articular and extra-articular are complex injuries, which require meticulous soft tissue care to avoid pitfalls and complications. Often these patients are multiply injured with many risk factors for the development of postoperative complications.[35]

For follow-up, we chose to utilize the WOMAC score, which is a validated, objective functional outcome measure of knee function and arthritis.[15,16] Initially designed for osteoarthritis, the scale has been utilized for outcome following fractures about the knee. We utilized the self-administered horizontal visual analogue scale (score 1-10) for pain, stiffness, and function. Our series of patients had poorer objective outcome scores compared to the subset of patients with high-energy plateau fractures reported by Stevens et al.[15] The authors may have utilized the 5-point Likert scale as opposed to the 10-point scale we utilized. While their patient number was smaller than ours, they had a longer follow-up of 8.3 years (7.8 years when only the Schatzker IV, V and VI fractures are considered) compared to 17 months in the current series.

Limitations of this study include the fact that methods of definitive fixation of fractures varied and changed over time as newer implants and techniques were introduced. There was no standardization of definitive fixation techniques. Not all fracture patterns are amenable to the same fixation constructs, however. Furthermore, some patients were temporized in a knee spanning external fixator and some were not. Scarring about the quadriceps mechanism may be partially responsible for some restricted range of knee motion seen in some members of our cohort. Errors in measurement of the radiographs is also a potential problem.

In conclusion, the use of soft tissue friendly approaches proved to be beneficial. Schatzker V and VI fractures are severe injuries that often present with severe associated injuries and are a high risk for complications. Good clinical results can be obtained by adhering to the principles of osseous stabilization, meticulous soft tissues handling, and delay in definitive stabilization until the soft tissue envelope has healed. As would be expected with intra-articular injuries, radiographic failure correlates well with a poorer functional outcome in these high-energy tibial plateau fracture patterns. This information will help guide physicians to counsel their patients when such an injury occurs.

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