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Review Article

MINIMALLY INVASIVE TREATMENT OF PILON FRACTURES WITH A LOW PROFILE PLATE: REVIEW

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ABSTRACT

Objective: To determine the results of ''biologic fixation'' with a minimally invasive plating technique using a newly designed low profile ''Scallop'' plate in the treatment of pilon fractures. ***Design:*** Retrospective case series.

Setting: A tertiary referral center.

Patients/participants: Seventeen patients were treated between 2015 and 2017 for a tibial plafond fracture at Department of Orthopaedics,The First Affiliated Peoples Hospital of Yangtze University,Jingzhou,Hubei,with a newly designed low-profile plate. Eleven of the fractures (65%) were high-energy injuries. Two fractures were open.

Intervention: Staged surgical treatment with open reduction and fixation of the fibular fracture and application of an external fixator was performed in 12 cases. As soon as the soft tissues and swelling allowed, i.e. skin wrinkling, the articular surface was reconstructed and simply reduced, if necessary through an small incision, and the articular block was fixed to the diaphysis using a medially placed, percutaneously introduced flat scallop plate. In the remaining five cases the operation was performed in one session.

Main outcome measurements: Time to healing and complications including delayed union, non-union, instrument failure, loss of fixation, infection, quality of reduction and number of reoperations were evaluated. Quality of results and outcome were graded using the ankle–hindfoot–scale and a modified rating system.

Results: All patients went on to bony union at an average time of 14 weeks. There were no plate failures or loss of fixation/reduction. Two superficial wound healing problems resolved with local wound care. At an average follow up of 17 months (range 6– 29 months) eight patients (47%) had an excellent result; seven (41%) had a fair result whereas two (12%) had a poor result. The average ankle–hindfoot–score was 86.1 (range 61–100). Four patients have had the hardware removed and one of them is awaiting an ankle arthrodesis.

Conclusions: Based on these initial results, it appears that a minimally invasive surgical technique including new low profile plate can decrease soft tissue problems while leading to fracture healing and obtaining results comparable with other more recent series. We believe that this new ''Scallop Plate'' is effective for the treatment of pilon fractures and should be used in conjunction with a staged procedure in the acute trauma setting.

Keywords: Pilon Fracture, Minimally invasive Plating.

INTRODUCTION

Since the classic paper by Ru ¨edi and Allgo ¨wer published more than two decades ago, the operative treatment of displaced pilon fractures is widely accepted [1-5]. The initial enthusiasm was tempered, however, by the significant soft tissue problems seen in later series [6]. It became clear that there are two very different types of pilon fractures. One is the relatively low energy torsional force that leads to a spiral fracture extending from the distal diaphysis into the metaphysis and ankle joint. The results of the surgical treatment of these fractures are generally good [1, 7, 8]. The second type represents a high-energy trauma in which an axial force drives the talus into the plafond causing a complex intra-articular fracture with metaphyseal impaction and comminution. It is this high-energy pilon fracture that still represents a major challenge to the treating physician. Regardless of the pilon fracture type, the key steps underlying successful treatment are,

According to the AO Principles:

1. open reduction and internal fixation of the fibula (when fractured) re-establishing the lateral column length;
2. anatomic reduction of the articular surface of the distal tibia;
3. bone grafting of the distal tibia;
4. buttress plating (usually medially) to prevent deformity (usually varus) of the distal tibia.

Despite adhering to these principles, however, it is often the integrity of the soft-tissue envelope that ultimately determines the outcome. Concerning rates of wound healing complications, osteomyelitis, and even below knee amputations have been documented in the literature with treatment of these difficult fractures [6]. These poor results have encouraged many trauma surgeons to consider external fixation techniques [9-13]. Although the incidence of wound related complications have been decreased by these external fixation techniques, an anatomic reconstruction has been difficult to achieve, leading to high rates of deformity, non-union/mal-union and early post-traumatic arthrosis of the ankle joint [14]. These efforts led to the development of a staged approach [3, 15-18] combining early open plate fixation of the fibula and temporary (but not necessarily anatomic) ‘‘bridging’’ of the pilon fracture component by means of ligamentotaxis with an external fixator. Subsequent open reduction and internal fixation techniques of the tibia are performed once the soft tissue envelope permits. Recently percutaneous plating techniques have gained popularity as an attractive alternative to allow stable fixation in a ‘‘biologically’’ friendly manner, and with less soft tissue and healing complications [19, 20]. The purpose of this study is to report our early experience in treating pilon fractures using a minimally invasive ‘‘percutaneous’’ technique with a low profile Scallop plate.

MATERIALS AND METHODS

All patients treated for a pilon fracture using the scallop plate were identified. The malleable scallop plate is a modification of the semitubular Synthes plate with rounded edges to allow easy, percutaneous application to the bone. For fixation 4.0 mm cortical low profile screws are used. The pilon fractures were classified according to the Ru ̈edi–Allg[7] as well as the AO-comprehensive classification system. The Gustilo classification was used to grade the open injuries[21]. In addition, closed soft tissue injuries were classified using the Tscherne classification (Table 2). The quality of articular reduction and alignment was judged on intra-operative radiographs using the criteria of Anglen et al. [14]: a reduction was designated excellent if there was no gap or step-off in the articular surface, a symmetrical mortise, and normal alignment of the joint to the shaft; good if there was less than 2 mm of gap or step-off, less than 1 mm of mortise asymmetry, and normal alignment; fair if there was 2– 4 mm of gap or step-off, 1–2 mm of asymmetry, or up to 10of deformity in alignment; or poor if there was more than 4 mm of gap or step-off, more than 2 mm of asymmetry, or more than 10of angular deformity.

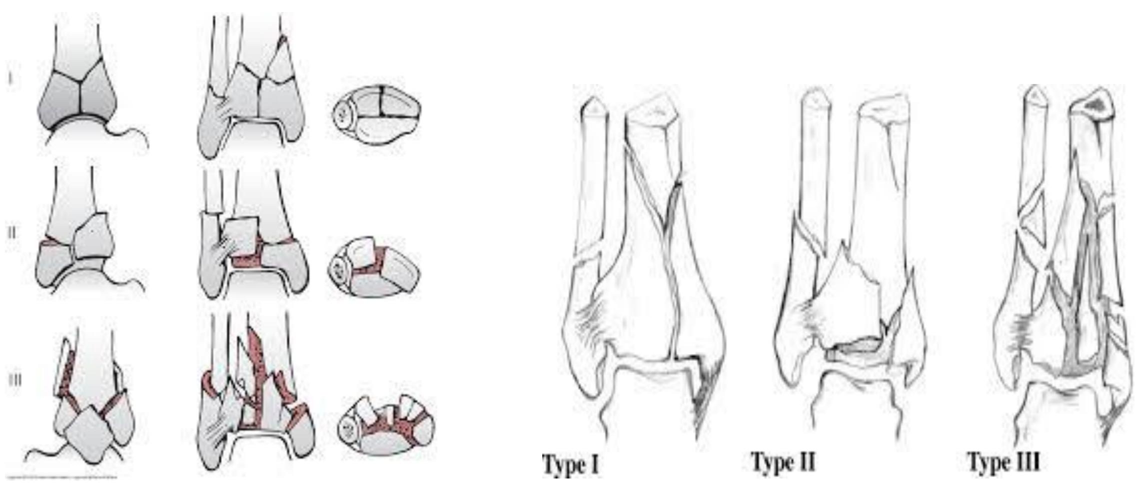

Figure: Ruedi and Allogwer clasifficatio on pilon fracture

Gustilo type I:	Open fracture with clean wound <1 cm, resulting from a inside out perforation.
Gustilo type II:	Open fracture with wound >1 cm, minor signs of contusion of surrounding soft tissues.
Gustilo type III A:	Extensive soft-tissue laceration, but enough soft-tissue to cover fractured bone.
Gustilo type III B:	Extensive soft-tissue laceration with periosteal stripping and bone exposure.
Gustilo type III C:	An open fracture with arterial injury requiring repair.

Table 1: Gustilo classification of open fracture.

Bony union was determined radiologically by crossing trabeculae across the original fracture lines and clinically by the patient's ability to fully bear weight. No evidence of bony healing at 6 months after the injury was classified as a non-union. Posttraumatic osteoarthritis was evaluated on anteroposterior, mortise and lateral radiographs obtained at the last followup visit: none to mild arthritis was present if there was 1–2 mm of joint narrowing, limited sclerosis and insignificant osteophytes. Moderate if there was 2– 4 mm of joint narrowing, more sclerosis and osteophytes, and severe if there was complete loss of joint space, extensive sclerosis, and collapse of tibia or talus. To evaluate the clinical results, the validated general health care questionnaire established by Kitaoka et al.[22] was used. This ankle–hindfoot scale developed by the American Orthopaedic Foot and Ankle Society incorporates both subjective and objective factors into numerical scales to describe function, alignment, and pain[22]. In this scale a score of 100 points is possible in a patient with no pain, full range of sagittal and hindfoot motion, no ankle or hindfoot instability, good alignment, ability to walk more than six blocks, ability to ambulate on any surface, no discernible limp, no limitation of daily or recreational activities, and no assistive devices needed for ambulation. In this scale 50 points have been assigned to function, 40 points to pain, and 10 points to alignment.

Grade O:	Little or no soft tissue injury
Grade I:	Significant abrasion or contusion
Grade II:	Deep contaminated abrasion with local contusional damage to skin or muscle
Grade III:	Extensive contusion or crushing of skin or destruction of muscle; also subcutaneous avulsions, decompensated compartment syndrome, or rupture of major vessel

Table 2: The Tscherne classification of closed fractures.

A modified grading system combining radiographic and functional data was also used[2]. The clinical results were judged to be excellent if the patient had no pain, no deformity, normal X-ray and no stiffness. The results were adequate, if the pain appeared only with sports or intensive activity, there was no deformity, minimal radiological signs and minimal stiffness. The result was deemed to be poor, if there was pain with walking, clinical and radiological deformity with radiographic changes of osteoarthritis or non-union and restriction of 50% or more of the ankle and subtalar motion.

Surgical technique:

For acute reduction of the fracture and stabilization the patient is placed supine on a radiolucent operating table. Pre-operative intravenous antibiotics are given. A tourniquet is applied. We always use regional anesthesia. The first step is open reduction and internal fixation of the fibular fracture, which will establish the lateral column length. Through a standard posterolateral incision, the fracture is reduced and either a onethird tubular plate or a 3.5 (LC-) DCP is used to fix the fibula. The wound is closed using 3-0 nylon Allgo ¨wer– Donati sutures. A triangular external fixator is then placed spanning the ankle joint. Two pins are placed proximally in the anteromedial aspect of the tibia and one centrally threaded pin is placed through calcaneus. Using ligamentotaxis and the re-established lateral column the pilon fracture is temporarily reduced. The relative stability achieved by this construct stabilizes the soft-tissues, improves patient comfort and promotes swelling reduction. Repeat debridements of open traumatic wounds can be managed without disturbing the fixation. While waiting for the soft tissues to recover, additional radiographic studies can be performed to delineate the exact fracture pattern and to plan the reconstructive procedure. We regularly obtain a preoperative CT scan during this time period. Staged definitive reconstruction is undertaken as soon as the soft tissues permit. The appearance of wrinkles is usually a sign that the soft tissues are amenable to surgical intervention. The patient is positioned supine on a radiolucent table with tourniquet. Careful evaluation of the preoperative radiographs and especially the CT scan should have determined the ideal placement of reduction clamps and lag screws for reconstitution of the articular surface. Ideally this is done through stab incisions. If pre-operative planning has shown that percutaneous fixation is not possible, reduction of the articular surface is achieved through a limited anterior arthrotomy. This allows for direct visualization of the reduction as well as bone grafting and/or application of a small anterior plate. After reconstruction and fixation of the articular surface the meta diaphyseal part of the fracture is addressed. The length of the needed scallop plate is estimated based on the pre-operative films. This is confirmed by placing the plate on the skin while checking the position with fluoroscopy. The plate is easily contoured to fit on the anteromedial aspect of the distal tibia. After bending and twisting the plate using plate benders, the anticipated position is again checked using fluoroscopy. Next, one anteromedial incisions is made at the proximal end of the anticipated plate position, and one at the distal end. A tunnel connecting these two incisions is carefully made by advancing a Kelly clamp from distal to proximal or from proximal to distal. A strong suture (e.g. Ethibond) is tied through the first hole in the plate. The Kelly clamp can then be used to help pull the scallop plate through the subcutaneous tunnel under radiographic visualization. For the fixation of the plate 4.0-mm cortical low profile screws (Synthes, Paoli, PA, USA) are placed through small stab incisions. The importance of an interfragmentary lag screw cannot be overemphasized. This can usually be placed in the midportion of the plate. Due to the flexibility of the plate a very good bone–plate contact is achieved. If necessary, cancellous bone graft can be placed at the fracture site through stab incisions under fluoroscopic control. When final radiographic control shows adequate reduction and fixation, the external fixator is removed. The tourniquet is deflated and hemostasis is obtained. The wound is meticulously closed over drains using 3-0 nylon Allgo ¨wer–Donati sutures. A bulky cotton dressing with a posterior plaster splint maintains the ankle in neutral position. On the first post-operative day gentle physical therapy is started with only toe-touch weight bearing (up to 20 lbs.) on the affected side. On the second postoperative day the splint is removed and a Cam walker boot is applied. At that time the patient starts with gentle range-of-motion exercises of the foot, ankle and knee. Activity may be advanced to partial weight bearing (40–60 lbs.) usually at 6 weeks. Full weight bearing is not permitted until full bony healing is confirmed radiographically, usually by 8–12 weeks post-operatively.

Figure: Plain X-Rays showing Ruedi and Allogwer type III

RESULTS

Seventeen pilon fractures have been treated using the scallop plate by the two senior authors. There were 2 female and 15 male patients with an average age of 48.1 years (range 27–78 years). Five of the fractures were classified as low-energy injuries, whereas 12 fractures involved high-energy trauma. Five fractures were AO class C1, four AO class C2 and eight AO class C3 fractures. According to the Ru ¨edi–Allgo ¨wer classification[7], this corresponded to five Type 1, four Type 2 and eight Type 3 fractures. Sixteen patients (94%) had associated fractures of the fibula. Fourteen fractures were closed (82%), three were open (18%). Using the Tscherne classification for softtissue injury three patients presented with a grade 0 lesion, three with a grade 1 lesion, three with a grade 2 and two with grade 3. For three patients the Tscherne classification was not available. Associated injuries occurred in five patients (29%). One polytrauma patient presented with closed head injury, thoracic contusion, closed ipsilateral femoral fracture and traumatic ipsilateral sciatic nerve palsy. Two patients presented with contralateral calcaneus fractures, one of these two had an ipsilateral lower leg compartment syndrome. One other patient presented with a closed head injury associated with a fracture of the base of the fifth metacarpal and finally one other patient had suffered an ipsilateral Lisfranc injury and fractures of the first and second metatarsal. Ten patients (59%) were directly brought to our hospital whereas the other seven patients (41%) were initially treated at an outside hospital. Of those patients that received their initial care at an outside hospital five had been treated with ORIF of the fibula and application of an external fixator. The other two patients were initially treated with closed reduction and application of a splint. The ten patients cared for from the beginning on at our institution had in seven cases been treated with our standard staged procedure protocol; the three others have been treated with a one-time procedure. Eleven patients were treated with ORIF of the fibula and application of the external fixator on the day of injury; three other patients had the same procedure 24 h after the initial injury. In three patients second look operations had to be performed before the final plating of the tibia. Two patients with open fractures (Gustilo type II) required irrigation and debridement, which were done in one patient only once with combined exchange of the external fixator, and twice in the other patient. The mean time interval from injury to definitive surgical treatment in the group that initially underwent placement of an external fixator (staged group) was 12.1 days (range 3–28 days), for those not treated with an external fixator this period was 9.2 days (range 1–25 days). All patients were operated upon under regional anesthesia. The mean operative time was 160 min (86– 241 min). In ten patients a tourniquet was inflated for an average time 138 min (range 103–223 min). The mean blood loss was 110 cc (range 20–300 cc). In ten patients an anterior arthrotomy was performed for better evaluation of the articular surface. In one case a fibular plate that had been placed at the outside hospital was revised to a longer plate. In only four (24%) patients the medially applied scallop plate was sufficient to hold the reduction of the articular surface. These were all Ru ̈edi–Allgo ̈wer type I or II fractures. Post-operative radiographs revealed excellent reduction in nine, good reduction in six, and fair in only two patients. In 15 patients (88%) wound healing was uneventful. One patient with a Ru ̈edi–Allgo ̈wer type I fracture had a delayed wound healing of the fibular incision, which resolved with local wound care. One patient with insulin dependent diabetes mellitus and a Ru ̈edi–Allgo ̈wer type II fracture also had a delayed wound healing of the lateral incision, needing multiple wound debridements as an outpatient, but finally healed. There were no (superficial or deep) infections of the anterior or medial wounds. The average hospital stay for the 11 patients with an isolated pilon fracture was 3.5 days (range 2–8 days), 5 patients with associated injuries stayed for an average of 8.2 days (range 3–15 days). All patients have been followed for a mean of 17 months (range 6–29 months). Time to bony healing averaged 14.1 weeks (range 10–23 weeks). There were no non-unions; all fractures healed with abundant callus formation. No breakage of the scallop plate has been seen, despite its malleability and thinness. At the latest follow up the average ankle arc of motion was 30(range 15–50). Radiological studies show no evidence of arthritis in ten patients (59%) and moderate arthritis in seven (41%). Eight patients complain of occasional pain while four of these use pain medication. Four patients have had their hardware removed partially or completely, one of them is currently awaiting ankle arthrodesis. Using the ankle–hindfoot–scale the average score was 86.8 (range 61–100). The patient with the lowest score is a polytrauma patient with an associated traumatic sciatic nerve lesion. Using the modified [2]rating system we had eight patients (47%) with an excellent outcome, seven patients (41%) with an adequate outcome and two patients (12%) with a poor outcome. In the Ru ¨edi–Allgo ¨wer type I fracture group four results were excellent and one adequate. In the Ru ¨edi–Allgo ¨wer type II group one patient had an excellent, two patients an adequate and one a poor result. In the Ru ¨edi–Allgo ¨wer type III group there were three excellent, four adequate and one poor result.

DISCUSSION

Untimely or inappropriate treatment of a tibial pilon fracture can lead to disastrous complications[6]. Treatment strategies have evolved from initially nonoperative, conservative methods to subsequent open reduction and anatomic internal fixation as introduced by Ru ¨edi and Allgo ¨wer and more recently to "the biologic'' approaches. Each of these strategies has pros and cons. Traction through a calcaneal pin in a Bo ¨hler frame can reduce the fracture partially by ligamentotaxis without compromise of the soft tissue envelope, but the prolonged bed rest during consolidation is not acceptable. Plaster immobilization can be used for minimally or non-displaced pilon fractures[23, 24] or in those patients with associated medical problems that preclude an operative procedure[4]. Casting, however, of Ru ¨edi type II or III fractures seldom leads to satisfactory results[23]. Perfect or near perfect alignment with good clinical outcome has been achieved by standard open reduction and internal fixation[8]with favorable long-term results in up to 90% of the cases[1, 7]. These good results have been almost exclusively achieved (75% respectively 90% of the time) in patients sustaining low energy skiing accidents and reproduction of these excellent results has been shown to be difficult. Teeny and Wiss[6]showed in their series of 60 pilon that fractures treated according to AO principles a very high complication rate. In their group with 60% high-energy injuries they achieved only 50% good and fair results. Complications such as wound dehiscence, infection, non-union, mal-union or implant failure were seen in 50% of their patients. Ru ¨edi III type fractures fared by fare the worst with a 70% complication rate and with a 37% infection rate. A possible explanation for these poor results can be that the average time between injury and operative treatment only 5.6 days and the use of formal open reduction and fixation with standard bulky implants. In addition, the surgery was performed by a large group of surgeons of different training levels. This dichotomy between the long-term outcome (and complication rates) in low versus high-energy pilon fractures has clearly been reflected in many other studies[2, 24-26]]. In order to minimize the complication rate and problems related to internal fixation, alternative fixation techniques using external fixation have been introduced. Wyrsch et al.[27]reported on a randomized prospective study comparing the results of ORIF with external fixation for those pilon fractures and concluded that external fixation was associated with fewer complications than internal fixation. Albeit only a limited number of patients they[27]did not find a difference in long-term outcome. McDonald[12]advocated a non-bridging Ilizarov technique for pilon fractures. In his series of 13 pilon fractures 84% of the fractures healed within 16 weeks. Ninety-one percent reported no or only mild pain with an average range of motion of the ankle from 12 of dorsiflexion and 25 of plantar flexion. Nine patients experienced at least one pin track infection. One patient needed a second operation for delayed union with bone grafting and eventually healed and a second patient was treated for a combined mal-union/non-union with an ankle arthrodesis. This was the only mal-union in this series. Anglen[14]found 16 complications in 15 of 34 pilon fractures treated with a hybrid external fixator leading him to conclude that hybrid external fixation for pilon fractures does not fulfill the theoretical advantages. In a meta-analysis of 187 patients in seven studies using external hybrid fixation[28], there were 40 pin tract infections (21%), and five septic arthritis and deep infections (5%). Pugh and Wolinsky[29]reported that ORIF, unilateral external fixator or a ring hybrid external fixation are all equally efficacious in achieving bony union but that the mal-union rate in the external fixator groups was higher. In order to achieve better articular reduction Bone[30] treated 20 patients with severely comminuted or open pilon fractures using a delta frame external fixator and ORIF with minimal soft-tissue dissection using either screws or small plates to stabilize the articular surface. Besides two minor pin tract infections no wound healing problems were encountered. Five patients required a secondary operation to achieve bony healing. Fourteen patients (70%) had fair or poor results with two patients requiring arthrodesis for posttraumatic arthritis. In order to combine the benefits of ORIF (direct visualization) with the benefits of external fixation (soft tissue protection) staged operations have been introduced[3, 16, 17]. Two large studies have been reported using this protocol[3, 17]. The fractures included 70 Ru ¨edi–Allgo ¨wer type III (AO classification Type C3) fractures (25 open fractures). The time interval between the application of the external fixator and definitive ORIF ranged from 12.7 to 24 days. Although all wounds eventually healed, seven patients (10%) had partial thickness skin necrosis. Three deep infections occurred (2.1%) with one subsequent below-knee amputation. In our study group two patients (12%) presented with delayed or problematic wound healing over the lateral fibular incision. One of the two (Patient 12) was an insulin dependant diabetic, a patient population almost ubiquitous for complications after surgery around the ankle[31-33]. The other patient (Patient 3) had suffered a closed, low energy, twisting Ru ¨edi–Allgo ¨wer type I fracture, which was stabilized immediately upon arrival in a one-stage procedure. Significant post-operative soft tissue swelling led to delayed wound healing over the later fibular incision. None of our patients developed any wound problems on the medial (percutaneous) tenuous soft tissue side utilizing this surgical technique or hardware, the focus of this review. Patterson and Sirkin[3, 17]describe one mal-union and one non-union requiring secondary interventions. While Sirkin[17]does not comment on the outcome of his patients, Patterson[3]had 91% good and fair clinical results and 73% anatomic reductions. One of our patients developed early posttraumatic arthritis and is currently awaiting ankle arthrodesis. He had a Ru ¨edi–Allgo ¨wer type III pilon fracture and was noted intra-operatively to have severe articular surface damage. Despite a good initial radiographic appearance, rapid degenerative changes occurred. Obviously, one of the main predictors of long-term outcome is the initial cartilage damage sustained at the time of impact[34]. Of fractures with a good reduction 89% of the outcomes were rated as good or excellent in two studies[4, 24]. For those patients with minimal initial cartilage damage but with an intra-articular mal-union, posttraumatic arthritis will develop eventually but slower. The standard radiographic images are anteroposterior, lateral, and mortise views. The initially often difficult interpretation of the exact fracture pattern can be facilitated by repeating the X-rays in traction or after application of the external fixator. For even better understanding of very comminuted fracture patterns and pre-operative planning the use of computed tomography (CT) scanning is helpful[4, 5, 18, 35]. The application of single screws to fix major fracture fragments is facilitated by pre-operative planning CT scanning[35] i.e. assuring ideal location and limiting the exposure required to identify fracture planes. During the actual surgery it is of great help to have a well-trained and experienced radiology technician to get the maximum information with fluoroscopy during the reduction of the fracture and the application of the plate while keeping the actual fluoroscopy time low. The bulky medial plates, traditionally used in pilon fractures, can not only lead to wound healing complications but they often cause long-term pain especially when wearing boots or shoes. The need for removal of hardware seems less frequent since we have started using the scallop plate and 4.0-mm (small head) cortical screws probably due to their low profile. Only one patient complained of medial pain related to the plate, which resolved after removal of hardware. One other patient had an anteriorly placed small fragment articular buttress T-plate removed because of painful anterior impingement. A third patient had the removal of hardware in anticipation of an arthrodesis and finally the last patient for non-medical reasons (to be accepted in the NY Fire Department). Although the scallop plate is much thinner than the standard 3.5 DCP or 3.5 LC–DCP, we have not seen hardware failure or loss of reduction. It is well established that the type of fixation (rigid vs. biologic) affects the type of osteogenesis (direct vs. indirect healing)[36]. This seems to be reflected by the finding of abundant callus in our patients treated with the flexible scallop plate. Whether this is due to the mechanical properties of the plate, the percutaneous placement or a combination of both is unclear. Locked plating of distal tibia/pilon fractures with anatomically shaped plates has recently gained favor. They are naturally thicker and stiffer, and do not allow the same indirect healing in the metaphysis. Only time will tell which is a better treatment option.

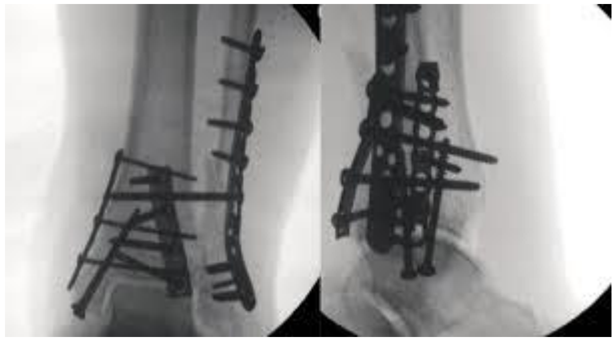

Figure: AP and lateral radiographs of ankle and of lower leg after application of spanning external fixator and ORIF of peroneus.

CONCLUSION

We believe that the scallop plate is a useful tool for the operative treatment of pilon fractures. This can be accomplished utilizing only percutaneous fixation for Ru ¨edi–Allgo ¨wer I and II pilon fractures. For Ru ¨edi–Allgo ¨wer III fractures one still requires an arthrotomy for open reduction of the articular surface. The location of the arthrotomy for the articular open reduction should be placed where most applicable as determined by the exact character and location of the various fracture lines on the CT scan; the scallop percutaneous medial plate can then be utilized to attach the reduced and stabilized articular segment to the more proximal tibial diaphysis. In addition, for those Ru ¨edi–Allgo ¨wer III fractures that are not salvageable, it can be used to provide an internal splint allowing consolidation of the bone stock without compromising the soft tissues for a subsequent or staged arthrodesis.

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