Original Clinical Article

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Ogden Type I to III tibial tubercle fractures in skeletally immature patients: is routine anterior compartment fasciotomy of the leg indicated?

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Abstract

Purpose Determine the frequency of compartment syndrome of the leg after displaced, operatively treated modified Ogden I to III tibial tubercle fractures (TTFxs), evaluate the preoperative assessment and use of advanced imaging, and need for prophylactic fasciotomies.

Methods Retrospective analysis of operatively treated, displaced modified Ogden I to III TTFxs, at our level 1 paediatric trauma centre between 2007 and 2019. Modified Ogden Type IV and V fracture patterns were excluded. Fracture patterns were determined by plain radiographs.

Results There were 49 modified Ogden I to III TTFxs in 48 patients. None had signs nor symptoms of vascular compromise, compartment syndromes or impending compartment syndromes preoperatively. In all, 13 of the 49 fractures underwent anterior compartment fasciotomy at surgery; eight of the 13 had traumatic fascial disruptions, which were extended surgically. All incisions were primarily closed. There were no instances of postoperative compartment syndromes, growth arrest, leg-length discrepancy or recurvatum deformity postoperatively. All patients achieved radiographic union and achieved full range of movement.

Conclusion The potentially devastating complications of compartment syndrome or vascular compromise following TTFx did not occur in this consecutive series of patients over 12 years. The presence of an intact posterior proximal tibial physis and posterior metaphyseal cortex (Modified Ogden TTFx Type I to III) may mitigate the occurrence of vascular injury and compartment syndrome. Plain radiographs appear appropriate as the primary method of imaging TTFxs, with use of advanced imaging as the clinical scenario dictates. Routine, prophylactic fasciotomies do not appear necessary in Ogden I to III TTFxs, but should be performed for signs and symptoms of compartment syndrome.

Level of evidence: Level IV

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Introduction

The first classification system for tibial tubercle fractures (TTFxs) was proposed by Watson-Jones in 1955,[1] in textbook format. In 1980 Ogden et al[2] modified this classification system to expand on the descriptions of the fractures (into the knee joint), the occurrence of fracture comminution and the need for operative fixation. Since 1980 multiple published studies have been published describing variants of TTFxs, with the proposition of expanding the classification system, or new classification systems entirely.[3-5] In 1985, Ryu and Debenham[5] proposed the addition of a Type IV fracture pattern, one which propagated posteriorly along the proximal tibial physis, exiting posteriorly either at the physeal level or distally through the metaphyseal bone. A Type V fracture pattern was proposed by Mosier and Stanitski, which was a combination of fracture patterns III and IV[6]. At present, this modified Ogden classification, with five fracture patterns, has been the most clinically utilized system for TTFx classification.

Vascular injuries and secondary compartment syndromes are well-documented complications in proximal tibial fractures, due to the proximity of the posterior neurovascular bundle and its lack of mobility. The first description of compartment syndrome in a TTFx was by Polakoff et al in 1986,[7] and since that time others have also reported compartment syndromes in association with TTFxs.[4,8-13]

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The mechanism for this complication has been proposed to be avulsion of branches of the anterior tibial recurrent artery, at the level of patellar tendon insertion.[13] The frequency has been reported to be as high as 20% in one series,[10] and has led to the recommendation to perform frequent or routine prophylactic anterior compartment fasciotomies.[4,11] The complications of open fasciotomies of the leg are well-known, and include infection, additional surgical procedures including skin grafting, increased length of hospital stay, fascial incisional hernias, unsightly leg scars, chronic exertional leg pain and permanent nerve damage.[14,15] Internal fasciotomies (without lengthy skin incisions) obviate the need for additional procedures and skin grafting, but are associated with incisional hernias and chronic pain.

At our centre the original Ogden or modified Watson-Jones classification (three fracture patterns) have been used for TTFxs, while fractures which exited through the posterior proximal tibial physis or posterior metaphyseal cortex (modified Ogden IV and V fracture patterns) were considered complete proximal tibial fractures, and not TTFxs. This was due to the fact the risks, complications and surgical treatment are different. Hence, in our experience with modified Ogden I to III TTFxs the frequency of compartment syndromes is rare, and the need for fasciotomies is low. In addition, there is an increasing interest in paediatric orthopaedics on the use of advanced imaging (i.e. CT and MRI) to enable highly-accurate fracture classification for theoretical risk stratification and guidance of treatment.[4] However, the negative implications of advanced imaging such as cost to the patient (CT and MRI) and increased exposure to ionizing radiation (CT imaging) are well-known. Hence, the question arose: should we routinely be obtaining advanced imaging for TTFxs and performing prophylactic fasciotomies for modified Ogden TTFxs I to III? The purpose of our study was to determine the frequency of compartment syndrome of the leg after displaced, operatively treated Modified Ogden I to III TTFxs, evaluate the preoperative assessment and use of advanced imaging and the need for prophylactic fasciotomies. We hypothesize the frequency of compartment syndrome and vascular compromise in patients with modified Ogden I to III TTFxs will be low.

Materials and methods

After institutional review board approval, a database query was performed to identify all patients < 18 years of age who underwent open reduction and internal fixation of a TTFx between January 1, 2007 and December 31, 2019 at St. Louis Children's Hospital, our tertiary-care, Level 1 children's hospital. The TTFx is characterized as traversing through the apophysis underlying the tibial tuberosity, with or without upward extension into the proximal tibial epiphysis, representing a Type-III (Salter-Harris classification) physeal fracture.[2] Only modified Ogden I to III fractures were included in the analysis; Ogden IV and V fractures were excluded (Table 1). Bilateral fractures were analyzed as distinct injuries.

The initial database query identified 95 fractures. There were 46 fractures which did not satisfy the inclusion criteria: 35 fractures were displaced tibial eminence fractures, five fractures were fractures (modified Ogden IV) that involved the posterior proximal tibial physis and/or metaphysis, two fractures occurred in a patient who were over the age of 18 years and four injuries were mislabeled and did not involve the proximal tibia. This left a total of 49 consecutive, operative, modified Ogden I to III TTFxs in 48 patients which were treated by 11 different paediatric orthopaedic surgeons.

Patient data collected from the institution database included age at injury, sex, body mass index (BMI), side affected and mechanism of injury. Plain lateral radiographs were used to assign an Ogden classification type (I, II, III) and modifier (A, B) to the TTFx (Fig. 1).[2] The fracture patterns seen on advanced imaging or determined during surgical open reduction and internal fixation were recorded. The individual treating surgeon determined the need for advanced imaging, arthrotomy and type of fracture fixation (Figs 2 to 4). The performance of a fasciotomy at operative repair and indications were documented.

Table 1. Modified Ogden classification; tibial tubercle avulsion fractures[6, 11]

Type	Definition
Type IA	Fracture distal to junction of ossification center of proximal tibial epiphysis and tuberosity
Type IB	Same as Type IA but with comminution of fracture fragments
Type IIA	Fracture extension to junction of proximal tibial physis
Type IIB	Same as Type IIA but with comminution of fracture fragment
Type IIIA	Fracture extends into joint through proximal tibial epiphysis with displacement of fracture fragment
Type IIIB	Same as Type IIIA but with comminution of fracture fragment
Type IV	Fracture extension transversely through proximal tibial physis with displacement of fracture fragment
Type V	Combination of Type III and Type IV fracture patterns, creating a 'Y' configuration

Fig. 1a,b) A 15 year-old male patient with Ogden 3A fracture pattern.

Fasciotomies, when performed, were done through the midline incision used for fracture reduction and fixation. A skin flap, anterior to the fascia was raised bluntly distally, just lateral to the tibial crest. Proximally, a small nick was made in the fascia with a pair of Metzenbaum scissors and the underlying muscle was dissected off the fascia. Metzenbaum scissors are then placed at the fascial edge and slowly pushed distally 12+ cm, staying 2 cm to 3 cm lateral to the tibial crest. The fascia is inspected for adequacy of release and muscle for bleeding and viability. A traumatic fasciotomy was noted if the patient's TTFx had significantly disrupted the fascia before the surgical intervention. Fracture fixation was dependent on fracture configuration, comminution, soft-tissue injury, patient age and weight. No tension band constructs were used in any patients. Screw fixation was the primary method of stabilization in 98% of fractures; additional fixation (Kirschner-wires and suture anchors) was used as clinically indicated. Postoperative immobilization was typically for six weeks with limited weight-bearing on crutches.

Primary outcome measures including preoperative and postoperative vascular compromise (defined as absence of distal pulses without return until after fracture reduction), compartment syndrome (diagnosed clinically using the presence of vascular compromise, paralysis, paresthesia, pain and pale skin tone), surgical site infection, implant failure and the occurrence of additional procedures were collected from clinical notes. Operative notes were reviewed to determine the nature of the operative intervention (reduction and fixation), the knee joint pathology

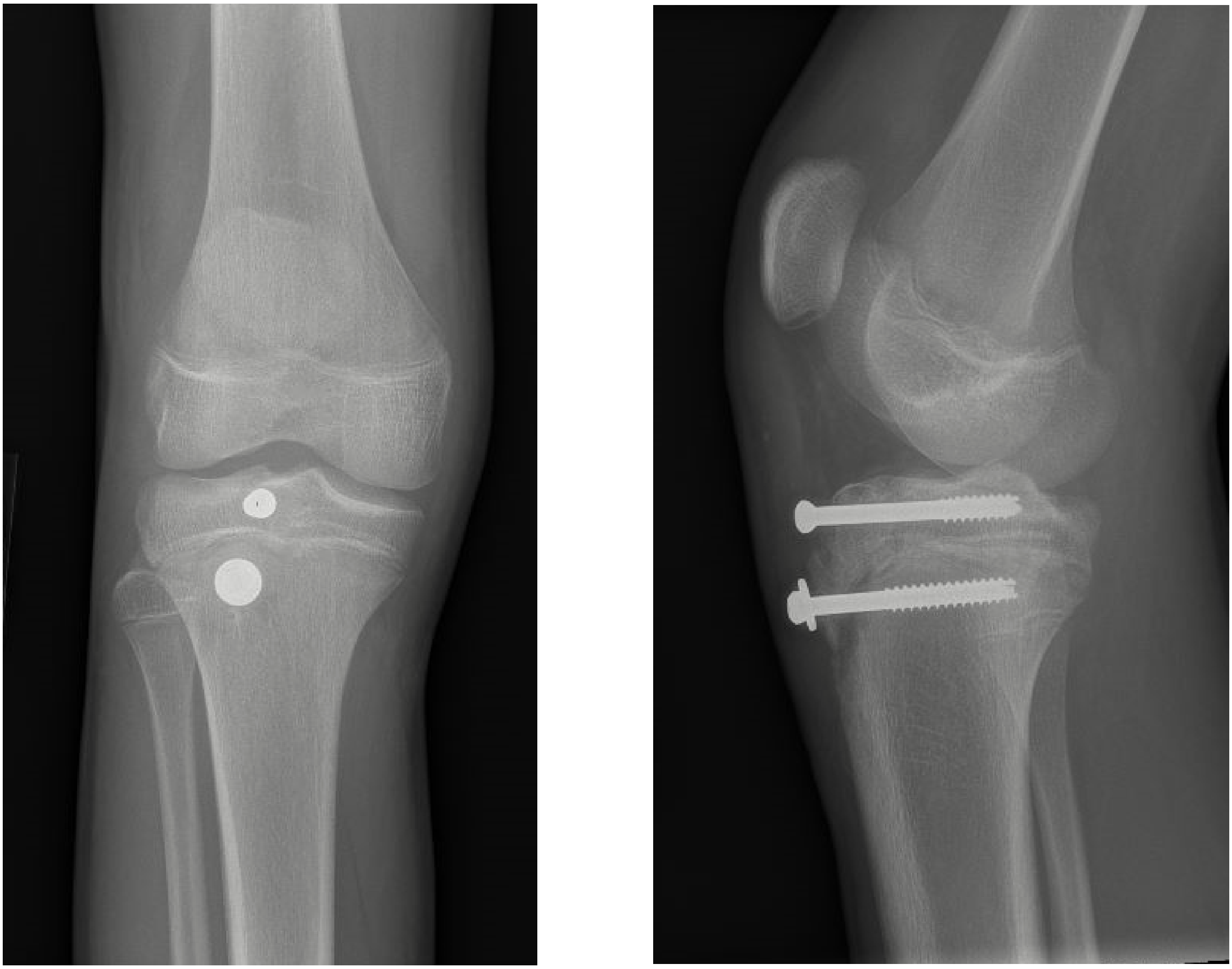

Fig. 2a,b) Two weeks after operative reduction and fixation with two 6.5-mm partially-threaded cannulated screws.

and any associated procedures performed at the time of tubercle fixation, including fasciotomy.

Secondary outcome measures included immediate postoperative weight-bearing status, progression of weight-bearing, type and duration of postoperative immobilization utilized, the use of a range of movement (ROM) bracing, length of total follow-up, knee ROM and most recent clinic visit notes. Length of total follow-up was the time from surgery until last clinic visit. Data collected from the last clinic visit included knee ROM, radiographic studies and the ability to ambulate. Full knee ROM was defined as 0° of extension to 135° of flexion. Means and standard deviations were calculated for all continuous variables (age, BMI, postoperative ROM, length of follow-up).

Results

In total, 48 patients with 49 TTFxs (modified Ogden I to III) were identified (19 right, 30 left), with a mean age of 14.9 years (SD 1.5; 10.1 to 17.7) at time of injury. There were 46 male patients and two female patients with a mean BMI of 25.4 kg/m^2 (SD 5.3; 17.8 to 38.6) at time of injury. There were two patients with reported Osgood-Schlatter disease prior to TTFxs. Basketball (47%) and jumping (14%) were the most common sporting activities associated with the injury (Fig. 5). Three fractures underwent preoperative advanced imaging (CT), which did not alter the fracture classification or surgical treatment, and all were Type III Ogden fractures. The reason for advanced imaging was not able to be discerned from the medical records. All of the excluded modified Ogden IV fractures were identified

Fig. 3a,b) A 16 year-old male; 14 months after operative repair with fracture solidly united.

Table 2. Surgical data

Surgeon ID	Number of fractures treated	Frequency of prophylactic fasciotomy, %	Frequency of advanced imaging, %
1	3	*100*	*0*
2	18	*5.6*	*0*
3	1	*0*	*0*
4	3	*0*	*33.3*
5	6	*16.7*	*0*
6	3	*0*	*0*
7	1	*0*	*0*
8	6	*33.3*	*16.7*
9	5	*80*	*20*
10	2	*100*	*0*
11	1	*0*	*0*

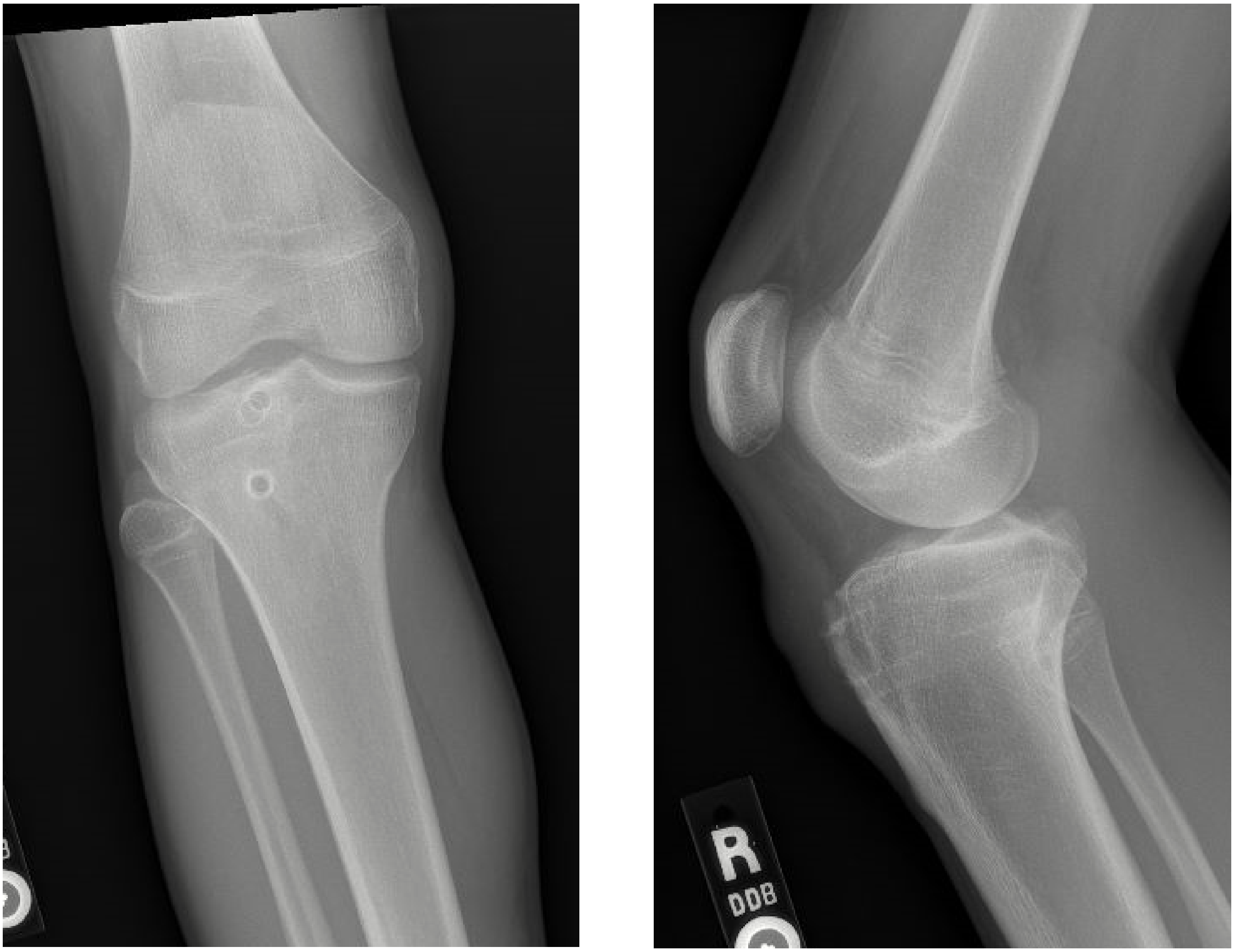

Fig. 4a,b) Two weeks after implant removal for anterior knee pain with activities.

Table 3. Breakdown by surgeon

Method	Percentage of patients
Reduction method	
Open reduction	*100*
Joint inspection	
Pre-reduction joint inspection (arthroscopic or open arthrotomy)	*12.50*
Post-reduction joint inspection (arthroscopic or open arthrotomy)	*2.10*
No joint inspection	*85.40*
Fixation method	
Screw	*32.70*
Screw + washer	*53.10*
Screw + washer + K-wire	*4.10*
Screw + suture anchor	*2.00*
Screw + washer + suture anchor	*2.00*
Screw + K-wire	*4.10*
K-wire	*2.00*

K-wire, Kirschner-wire

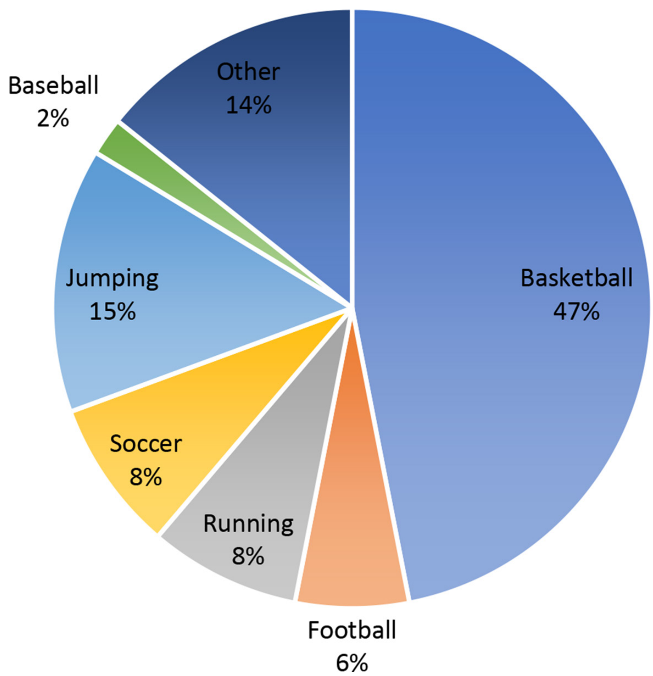

Fig. 5 Mechanism of injury for cohort.

on plain radiographic imaging. There were nine Type I fractures (one type A, eight type B), 11 Type II fractures (four type A, six type B) and 29 Type III fractures (15 type A, 14 type B) in this study.

None of the patients had signs nor symptoms of vascular compromise, compartment syndromes or impending compartment syndromes preoperatively. In total, 13 of the 49 fractures underwent additional anterior compartment fasciotomy at the time of surgical open reduction and internal fixation. All 13 fasciotomies were classified as prophylactic and were performed through the anterior surgical approach to the tibial tubercle. There was significant variability between surgeons, as documented in Table 2. All surgical incisions were closed primarily; none were left open. Eight of the 13 fractures, which underwent prophylactic fasciotomies, were determined to have small, incidental traumatic disruptions of the anterior compartment fascia due to the fracture. In these eight patients the fascial rent was extended distally with Metzenbaum scissors under direct vision. All the inspected muscle of the anterior compartment, after fasciotomies, was healthy without evidence of necrosis. There were no complications related to the additional procedure of anterior compartment fasciotomy. All fractures underwent open reduction and internal fixation, with 98% of primary stabilization from screw fixation (+/- washer); 12% had supplemental fixation (Table 3). In general, screw fixation was with 4.5-mm and 6.5-mm fully or partially threaded screws (Figs 2 and 3).

There were no instances of postoperative compartment syndromes, growth arrest, leg-length discrepancy or recurvatum deformity postoperatively. There were two instances of surgical site infection. In all, 13 fractures underwent screw/implant removal (Fig. 4). No other reconstructive surgery has been performed.

All patients achieved radiographic union. Mean follow-up time was 6.2 months (SD 10.3; 0.5 to 60.3). Immediately after surgery, 84% of patients were made non-weight-bearing, 8% were toe-touch weight-bearing, 6% were weight-bearing as tolerated and 2% were full weight-bearing. Postoperative immobilization was a long-leg cast in 14 fractures (29%), knee immobilizer in 30 fractures (61%), four fractures in a fiberglass splint (8%) and one fracture had no postoperative immobilization information. Patients started ROM at a mean of 4.0 weeks (SD 2.5; 1 to 12) after their operation and achieved full ROM at a mean of 12.5 weeks (SD 8.3; 4 to 44) postoperatively. Patients achieved ambulation without limp at a mean of 12.2 weeks (SD 8.0; 4 to 40) after their operation.

Discussion

The purpose of this study was to determine the frequency of compartment syndrome of the leg after displaced, operatively treated Modified Ogden I to III TTFxs, evaluate the preoperative assessment and use of advanced imaging and the need for prophylactic fasciotomies. Of the 49 Modified Ogden I to III TTFxs only three underwent preoperative advanced imaging (CT), which did not alter the fracture classification. In total, 13 of the 49 fractures underwent additional anterior, internal compartment fasciotomy at the time of surgical open reduction and internal fixation; eight had traumatic fascial disruption which were extended surgically. All incisions were primarily closed. We could not identify any instances of postoperative compartment syndromes, growth arrest, leg-length discrepancy or recurvatum deformity postoperatively in any patient. The potentially devastating complications of compartment syndrome or vascular compromise following TTFx did not occur in this series of patients.

The use of CT scans in the United States has increased more than three-fold since 1993 to approximately 70 million scans annually in 2008, and continues to increase dramatically.[16,17] While CT scans can provide great medical benefits, there is concern about potential future carcinogenic risks, because of the significantly higher radiation doses than conventional diagnostic radiographs.[17-19] In addition, the long-term radiation exposure is a major concern since children are more susceptible to radiation-related malignancies than adults, and have a longer life-span to express late effects.[20] In 2012, Pandya et al[4] described a unique classification system (A to D) which utilized CT scans to assess the 3D configuration of the fracture. This study has been widely quoted and reference and may have contributed to increased utilization of preoperative CT scan imaging of TTFxs, due to the significant frequency of compartment syndromes and vascular compromise reported (10%). In this study the use of plain radiographs adequately identified the TTFx pattern and the isolated use of CT imaging (three Ogden III fractures) did not contribute to correct fracture classification nor did it reclassify any fracture to a modified Ogden IV or V. Hence, if high-quality, diagnostic, plain radiographic imaging with orthogonal views of the proximal tibia can be obtained there does not appear to be compelling evidence CT scanning is necessary for fracture evaluation. In addition, direct visual inspection of the knee joint during surgery is possible to evaluate intra-articular structures which deserve surgical treatment. The use of a non-ionizing radiation imaging modality, such as MRI, may be a preferred modality to avoid ionizing radiation exposure rather than CT if there is concern for an intra-articular fracture or extension of the fracture posteriorly through the physis.

Compartment syndrome is a potentially severe complication which must be considered upon initial presentation of injury for any proximal tibia fracture, however, the first report of compartment syndrome was in 1986 by Polakoff et al.[7] They described two patients, the first was a Type IIIA fracture pattern "with posterior extension to the proximal medial metaphysis". The second patient had a Type IIA fracture pattern with a concomitant peroneal palsy which the authors attributed to "temporary ischemia" due to compartment syndrome. The radiographs for these two fractures were not published but the fracture description and the associated nerve palsy raise the question as to whether these injuries had fracture extension through the posterior cortex or physis, making them probable complete proximal tibial fractures (Type IV). Pape et al[13] reported two compartment syndromes, one Type IIIB TTFx and one Type IIA TTFx. Radiographs in the manuscript demonstrate the Type IIIB fracture pattern as accurate. However, the IIA fracture pattern was described as having "extension to the posterior cortex", which would now re-classify this as a Type IV fracture pattern. Since these two early studies there have been several subsequent studies on TTFxs and compartment syndromes.[4,8-12] If we re-classify two of the Polakoff et al[7] and Pape et al[13] patients to modified Ogden IV TTFxs, based on the manuscript descriptions detailed above, there would be six modified Ogden I to III TTFxs with compartment syndromes and 13 modified Ogden IV TTFxs. A higher frequency of compartment syndromes in modified Ogden IV and V TTFx patterns would mechanistically be appropriate due to the sagittal and coronal instability of the distal fragment being able to compress/injure the posterior neurovascular bundle. Hence, there a few actual reported cases of compartment syndromes in modified Ogden TTFxs I to III in the literature.

The identification of a compartment syndrome and the performance of the appropriate fasciotomy and determination of its adequacy can be challenging. It is generally recognized that the threshold for a fasciotomy should be low, due to significant complications and adverse outcome of a delayed or missed diagnosis and treatment. However, as previously presented, fasciotomies have a known complication profile. The frequency has been reported to be as high as 20% in one series,[10] and has led some to recommend more frequent, prophylactic anterior compartment fasciotomies.[4,11] All of the 13 fasciotomies in this study were completed through the anterior incision for repair of the TTFx, and were primary closed; hence were internal fasciotomies. At the time of surgery, the treating surgeon made the determination to perform a prophylactic fasciotomy based on the patient's clinical scenario and their experience and training. Interestingly, eight of the 13 fractures which had prophylactic fasciotomies performed on them had fascial disruption at the time of open reduction and internal fixation. The presence of a significant fascial disruption likely influenced the surgeon to perform a more formal fasciotomy, and may be a more important indicator of the potential need for prophylactic fasciotomy. The frequency at which fasciotomy is used during fracture fixation varied widely (0% to 100%) between treating surgeons in this study (Table 3). In our experience, there remains uncertainty amongst orthopaedic surgeons regarding the need for anterior compartment fasciotomy during operative treatment of TTFxs.

However, because the chance of compartment syndrome exists in any tibial fracture, the surgeon needs to take into consideration injury mechanism, associated injuries, local soft-tissue injury and medical comorbidities when determining the need for anterior compartment fasciotomy. There is risk of compartment syndrome with displacement of the proximal tibial physis because the proximal tibial physis is at the same level as the trifurcation of the popliteal artery where the three major branches (peroneal, anterior tibial and posterior tibial arteries) divide.[21] Also, the lateral aspect of the tibial tubercle is the site of a fan-shaped group of vessels originating from the anterior tibial recurrent artery.[13] These vessels can become retracted under the fascia and into the muscles of the anterior compartment after being avulsed and lead to excessive bleeding within the anterior compartment.[4,13,22]

This study has several weaknesses. The retrospective nature of this study does not allow for standardization of the plain radiographic imaging, nor the indications of CT imaging. We cannot assess the impact of advanced imaging, such as CT or MRI, on fracture classification or surgical treatment. There is a chance, as detailed by Pandya et al,[4] that we underestimated the fracture pattern and instability, which would have potentially pushed some fractures to an Ogden IV or V fracture pattern. However, intraoperatively and postoperatively there were no fractures which demonstrated fracture pattern, comminution or instability which altered the planned fixation or impacted outcome. In addition, the reasons for performance of prophylactic fasciotomy in 13 fractures is a potential effect modifier that may decrease the likelihood of postoperative compartment syndrome. However, the fasciotomies were not performed for a known compartment syndrome, rather eight of the 13 had partial traumatic fasciotomies which were surgically extended due to potential muscle injury. Only five fasciotomies were performed for fullness or tightness of the anterior compartment but there was no compartment pressure monitoring prior to the fasciotomies. Lastly, while 98% of fractures underwent open reduction and screw fixation, the method of fracture fixation was not standardized and was dependent on surgeon experience and fracture location and comminution.

During this 12-year experience, no patients presented with, or developed, compartment syndrome or vascular compromise of the leg after a modified Ogden I to III TTFxs. To avoid unnecessary additional ionizing radiation exposure and expense, plain anteroposterior and lateral radiographs should remain the primary imaging modality for TTFxs. Advanced imaging (e.g. MRI) may be indicated for atypical clinical presentations (e.g. motor vehicle crash) or if there is concern that there may be a posterior proximal tibial physeal or metaphyseal fracture or intra-articular extension, that cannot be adequately evaluated by plain radiographs. In our experience, anterior compartment fasciotomies of the leg should not be prophylactically performed solely based on the presence of a TTFx but rather based on the signs and symptoms of compartment syndrome or vascular compromise and intraoperative findings (e.g. traumatic fascial disruption of the anterior compartment).

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ICMJE CONFLICT OF INTEREST STATEMENT

No conflicts exist for any of the authors pertaining to the submitted work.

AUTHOR CONTRIBUTIONS

CB: Substantial contributions to the conception or design of the work or the acquisition, analysis, or interpretation of data for the work, Drafting the work or revisiting it critically for important intellectual content, Final approval of the version to be published.

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