Semiextended Intramedullary Nailing of the Tibia Using a Suprapatellar Approach: Radiographic Results and Clinical Outcomes at a Minimum of 12 Months Follow-up

Roy W. Sanders, MD, Thomas G. DiPasquale, DO,† Charles J. Jordan, MD,‡ John A. Arrington, MD,§ and H. Claude Sagi, MD**

Objective: To evaluate the clinical and radiographic results associated with the use of a percutaneous suprapatellar (SP) portal and accompanying instrumentation for tibial intramedullary nail (IMN) insertion using a semiextended approach.

Design: Prospective, nonrandomized, nonconsecutive study.

Setting: Level 1 trauma center.

Patients and Methods: From June 2007 to January 2011, 56 fractures (55 patients) underwent intramedullary nailing of a tibia fracture with a semiextended approach through a SP portal. Radiographic and clinical follow-up examinations were performed at a minimum of 1 year after the index procedure. Measurements included bone healing, tibial alignment, knee range of motion, pain drawings, pain scoring (visual analogue scale), functional outcome (Lysholm and SF-36 scoring), evaluation of prenail and postnail insertion arthroscopic images of the patella-femoral (PF) joint (subgroup of study patients), and 1-year follow-up magnetic resonance imaging (MRI) scans (STIR and T2 gradient echo) of the knee to evaluate the PF joint cartilage. MRI scans were reviewed by an independent bone radiologist, whereas arthroscopic images were evaluated by an independent sports medicine fellowship-trained orthopaedic surgeon.

Results: Thirty-six patients (37 fractures) were available for follow-up at a minimum of 1 year (range: 12–49 months) after the index procedure. All but 2 fractures healed after the index procedure (94.6%). There was 1 radiographic malunion (2.7%). The mean Lysholm knee score was 82.14. Mean SF-36 physical and mental scores were 40.8 and 46.0, respectively. Mean arc of knee motion was 124.4 degrees for the affected extremity compared with 127.2 degrees for the contralateral knee. One patient (2.7%) complained of mild pain at the scar, but no patient complained of anterior knee pain either at the PF joint or at the anterior proximal tibia. In 13 of 15 patients undergoing an arthroscopic assessment of the PF joint, prenail and postnail insertion, no cartilage changes, or pressure points were seen either at the patella or at the trochlea groove. Two patients had grade II chondromalacia of the trochlea immediately after the procedure, but these did not correspond with either MRI scans or clinical findings at 1 year. When the remainder of the 1-year MRI scans were reviewed, 1 knee (2.7%) in a patient that did not have an arthroscopic examination was found to have grade II chondromalacia in the PF joint, but this did not correlate with the clinical examination, which was normal.

Conclusions: This is the first paper to critically document clinical and radiographic results using the percutaneous SP portal with the semiextended approach for IMN of the tibia. Our 1 year results indicate that the procedure resulted in excellent tibial alignment, union, and knee range of motion, with rare sequelae in the PF joint based on immediate arthroscopy and 1-year MRI scans and clinical examinations. Even more interesting was the absence of anterior tibial pain often found when a tibial nail is inserted in a standard fashion.

Key Words: suprapatellar, semiextended approach, tibial intramedullary nail

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2014;28:S29–S39). Reprinted with permission.

Accepted for publication February 10, 2014.

From the *Orthopaedic Trauma Service, Florida Orthopaedic Institute, Tampa, FL; †WellSpan Health, York, PA; ‡UHZ Sports Medicine Institute, Miami, FL; and §University Diagnostic Institute, Tampa, FL.

Supported by a research grant from Stryker Orthopaedics and the Tampa General Foundation.

Presented in part at the Annual Meeting of the Orthopaedic Trauma Association, October 6, 2012, Minneapolis, MN.

Study performed by the Orthopaedic Trauma Service, Florida Orthopaedic Institute, Tampa, FL.

R. W. Sanders is a consultant and received royalties from Smith-Nephew. H. C. Sagi is a consultant and receives royalties from Stryker. T. G. DiPasquale is a speaker for AO North America and Smith-Nephew. The other authors report no conflict of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions this article on the journal's Web site (www.jorthotrauma.com).

Reprints: Roy W. Sanders, MD, Orthopaedic Trauma Service, Florida Orthopaedic Institute, 5 Tampa General Circle, Suite 710, Tampa, FL 33606 (e-mail: ots1@aol.com).

INTRODUCTION

The tibia is the most commonly fractured long bone in the human body. In the 1940s, Küntscher developed a medullary nail for diaphyseal fractures that required reaming for insertion and canal fit.[1] Presently, reamed insertion of an intramedullary nail (IMN), with the additional placement of interlocking screws for axial and rotational stability, is the preferred method for managing unstable tibial diaphyseal fractures.[2] Entry portal placement for standard tibial nailing has traditionally been centrally behind the patella tendon in an

area between the articular surface (proximally) and the tibial tubercle (distally). This area is reached either through a patellar tendon-splitting or tendon-sparing approach, with the knee in flexion or even hyperflexion.[3,4]

With the development of locking screws, metaphyseal fractures became amenable to treatment with IMN. Although theoretically advantageous, IMN insertion for these fractures remains technically challenging. This is most notable with proximal third tibial fractures where the quadriceps and extensor mechanism complex attempts to extend the proximal fracture fragment, whereas the distal fragment remains flexed, resulting in a procurvatum deformity of the tibia.[5] Equally problematic is the fact that the metaphysis is conical in shape, making even a slightly angulated entry, result in a coronal plane (valgus/varus) deformity. As a result many additional techniques have been developed to solve these problems including blocking (poller) screws and plates.[6–8]

One technique used to correct proximal tibial malalignment at the time of IMN is the semiextended technique described by Tornetta et al.[9] This approach employs a partial medial parapatellar arthrotomy to subluxate the patella laterally. This allows IMN insertion with the knee in approximately 15 degrees of flexion. Satisfactory results have been reported with this technique, but an extensile approach is required compared with traditional IMN. As a result, a modification of the semiextended technique, known as the suprapatellar (SP) approach, was developed by Dean Cole, M.D. (personal communication) of Orlando, FL.[10] This is a percutaneous approach that uses an incision 2.5 cm proximal to the superior pole of the patella. After the quadriceps tendon is split in line with its fibers, a cannula system is employed both for tibial preparation and for IMN insertion.

This study is designed to review our experience with the SP approach for semiextended nail insertion. Our goal was to compare this technique to published reports of traditional IMN of the tibia with regard to postoperative alignment, healing, function, range of motion (ROM), and pain.

PATIENTS AND METHODS

Patients

From June 2007 to January 2011, 501 tibial shaft fractures were treated with an IMN at our level I trauma center. Of these, 55 patients (56 fractures) underwent IMN using a semiextended approach through a SP portal. Choice of this technique was at the discretion of the treating surgeon, based on fracture pattern, familiarity with the technique, and availability of instrumentation. This was a nonrandomized nonconsecutive series. All patients were skeletally mature, and both open and closed fractures were included. All fractures that were treated with this technique involved the tibial shaft including those that had a nondisplaced distal tibial extension. Shaft fractures with associated tibial plateau or pilon fractures requiring tibial plating in addition to the nail were excluded from the study. The Orthopaedic Trauma Association Classification was used to document each fracture type (OTA 42 A, B, C).[11] Each fracture was also classified based on its location according to the S.P.R.I.N.T criteria as proximal, proximal-middle, middle, middle-distal, and distal.[12] All fractures were operated on the same hospital admission as the initial presentation. All fractures underwent reamed, statically locked intramedullary nailing, with or without compression thru a titanium alloy nail, using 1 of 2 specially designed instrumentation systems for SP IMN insertion (T2 Tibial Nail; Stryker Orthopaedics, Mahwah, NJ; Trigen Meta Tibial Nail; Smith and Nephew, Memphis, TN) (Fig. 1, Table 1).

Evaluation of the Patella-Femoral Joint

During the initial period of data collection, we attempted to determine how best to assess injury to the patella-femoral (PF) joint. Consequently, after the first 26 cases, diagnostic arthroscopy was added to our procedure to better evaluate the PF joint before and immediately after nail insertion. Any damage to the PF joint that occurred intraoperatively would therefore be noted. In these cases, after the incision was made, a small amount of fluid was placed into the PF joint and both PF articular surfaces were inspected, and images were obtained. After completion of the procedure, but before closure, the knee was washed out, the arthroscope was reinserted, and the PF articular surfaces were again inspected, and images were saved. All images were then evaluated by an independent sports medicine fellowship trained attending to evaluate cartilage injury. Any changes were recorded using the Outerbridge scale; however, grade I was omitted because it is an "active" diagnosis, that is, requires probing of the lesion. Therefore, images were evaluated for Outerbridge grade II: Fragmentation and fissuring,

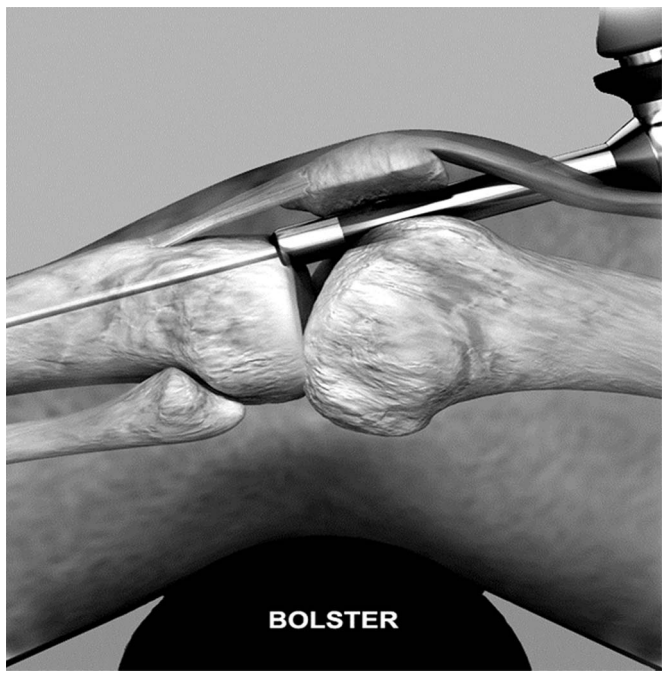

FIGURE 1. Cross-sectional representation of specialized cannula system placed in the SP portal with the knee in the semiextended position.

TABLE 1. Patient Data

	Sex	Age, y	Side	Nail Type	OTA Class	Open?	Fracture Level	Other ORIF?	Other Findings
1	F	70	Right	Stryker	42B1.3	N	MD	Ankle	PT 70, Infirmed
2	F	37	Right	Trigen	42A1.1	N	MD	Ankle	—
3	F	32	Left	Stryker	42C2.2	Open	PM + MI	—	R calc, R talus, R navicular, L spine
4	M	25	Left	Stryker	42C2.2	Open	PM + MI	—	R patella fx, CHI, skull fx
5	M	50	Left	Stryker	42B1.2	Open	MD	—	—
6	M	22	Left	Trigen	42B3.3	Open	MD	Ankle	—
7	F	48	Left	Trigen	43A2.3	N	MD	Ankle	—
8	M	58	Left	Trigen	43A2.2	Open	MD	Ankle	—
9	M	50	Left	Stryker	42A2.3	Open	MD	—	Degenerative tears M+L, OA knee
10	M	59	Left	Trigen	42A2.1	N	MI	—	—
11	F	50	Left	Stryker	42C2	N	PM + MI	—	Pulm cont, spleen lac, SDH, L2-5 fx, L IT, R ankle, R olecranon, pelvis
12	M	24	Right	Stryker	42C3.3	Open	MI	—	R fem shaft, C and L spine, spleen lac
13	F	34	Left	Stryker	42B3	N	MD	—	—
14	F	59	Left	Stryker	42A2.2	Open	MI	—	Preexisting OA knees
15	M	48	Left	Trigen	42C2.2	N	PM + MI	—	—
16	M	43	Left	Trigen	41A2.3	N	MI	—	—
17	M	76	Left	Trigen	42B1.2	N	PM + MI	—	R femur A + V, R dist fem, R tib, R calc, R MT, preexisting OA knees
18	M	42	Left	Trigen	42A3.3	N	MI	—	Pelvis and sacral fractures
19	M	50	Right	Stryker	42B2.3	N	MD	—	—
20	M	50	Right	Stryker	42B2.2	Open	MD	—	—
21	M	22	Left	Trigen	42A3.3	N	MI	—	—
22	M	18	Left	Trigen	42B2.3	N	MI	—	—
23	F	38	Right	Stryker	42C2.2	N	PM + MI	Ankle	—
24	M	20	Left	Stryker	42C3.2	Open	MI	—	CHI, C2, R acet, L fa, R hum
25	M	21	Left	Stryker	42A3.3	N	MI	—	—
26	F	41	Right	Stryker	42B3.3	N	MD	Ankle	—
27	F	59	Right	Stryker	42B2.3	N	MD	Ankle	Preexisting OA knees
28	M	63	Right	Trigen	42B2.3	N	MD	Ankle	Stroke on opposite side
29	F	30	Left	Trigen	42C1	N	MI + D	—	—
30	M	67	Right	Trigen	42A2.3	N	MI	—	L1, L4 compression fx, concussion
31	M	23	Right	Trigen	42B1.1	N	MI	—	—
32	M	25	Left	Trigen	42A3.3	N	MI	—	—
33	M	31	Right	Trigen	42A2	Open	MI	—	—
34	M	31	Left	Stryker	42A2	Open	PM	—	Malunion
35	F (L)	26	Left	Trigen	42B2.1	Open	MI	Ankle	—
36	F (R)	26	Right	Trigen	42C3.3	Open	MD	Ankle	—
37	F	40	Left	Stryker	42B1	Open	MI	—	Morbid obesity, preexisting OA knees

CHI, closed head injury; D, distal; F, female; fx, fracture; IT, intertrochanteric fracture; L, left; M, male; MI, middle; MD, middle distal; N, no; OA, osteoarthritis; P, proximal; PM, proximal middle; R, right.

less than 0.5-in diameter, grade III: fragmentation and fissuring, greater than 0.5-in diameter, or grade IV: Erosion of cartilage down to exposed subchondral bone.

Postoperative Protocol and Outcome Measures

Patients were made weight bearing as tolerated, immediately postoperatively.[12] All patients were taught active knee and ankle ROM exercises and a quadriceps strengthening regimen. Patients were evaluated initially at 2 weeks, and at monthly intervals until the fractures were radiographically healed, based on bridging bone seen on all radiographic views.[12] Additionally, all fractures were scored by the Radiographic Union Scale for Tibial fractures (RUST) method at 1 year.[13] During this follow-up time period, patients were asked to enroll in an institutional review board approved study to prospectively evaluate their outcomes related to this technique. For the purposes of the study, patients were brought back into the office at a minimum of 12 months. Those patients that were unavailable at 12 months were brought in whenever they could be located for an evaluation as long as it was 12 months after the index procedure.

TABLE 2. Follow-up Data

	Follow-up, mo	Pain Drawing	VAS	Lysholm Pain Component	Lysholm	SF-36 P/M	Affected Side ROM	Opposite Side ROM	Knee Scope?	Patello-femoral Arthroscopic Findings	MRI Results
1	47	N	0	25	83	27.7/27.9	0–115	0–115	N	—	Normal
2	28	N	0	25	95	56.0/58.2	0–130	0–130	N	—	Normal
3	12	N	0	25	98	38.5/57.4	0–135	0–135	N	—	Normal
4	12	N	0	5	73	31.8/30.7	0–110	0–110	N	—	Normal
5	12	N	0	25	89	51.5/59.0	0–140	0–140	Y	Normal, grade II preoperative	Normal
6	42	N	0	25	100	53.7/51.7	0–130	0–130	N	—	Normal
7	12	N	0	20	61	46.1/47.2	0–145	0–145	N	—	Normal
8	12	N	0	25	96	49.5/48.5	0–135	0–135	Y	Normal preoperative/ postoperative	Normal
9	12	MJL	0	10	60	35.9/26.4	0–125	0–135	Y	Normal preoperative/ postoperative	Normal
10	12	N	0	25	89	46.1/60.4	0–140	0–140	N	—	Normal
11	12	MJL	0	0	40	33.6/29.7	0–120	0–140	N	—	Normal
12	26	N	0	0	34	44.2/47.2	0–125	0–145	N	—	Normal
13	12	N	0	10	85	57.8/59.3	0–150	0–150	N	—	Normal
14	12	N	0	20	73	33.5/48.0	0–105	0–125	N	—	Preexisting OA
15	37	N	0	25	100	44.8/60.7	0–140	0–140	N	—	Normal
16	19	N	0	15	55	47.0/52.9	0–140	0–140	Y	Normal preoperative/ postoperative	Normal
17	13	MJL	0	20	63	26.0/37/3	5–110	20–75	N	—	Preexisting OA
18	12	N	0	25	100	37.2/38.5	0–110	0–120	Y	Normal >grade II postoperative	Normal
19	14	N	0	25	86	37.2/50.5	0–130	0–135	N	—	Normal
20	13	N	0	25	100	43.2/43.3	0–120	0–120	N	—	Normal
21	12	N	0	15	79	44.5/62/3	0–90	0–90	Y	Normal preoperative/ postoperative	Normal
22	18	N	0	25	100	58.9/50.8	0–120	0–125	Y	Normal >grade II postoperative	Normal
23	13	N	0	20	95	52.6/55.6	0–130	0–130	N	—	Grade II
24	15	N	0	25	81	45.3/59.8	0–130	40–130	N	—	Refused MRI
25	49	N	0	20	55	49.4/39.9	0–105	0–105	N	—	Normal
26	12	N	0	25	88	37.6/37.3	0–130	0–130	Y	Normal, grade II preoperative	Normal
27	12	N	0	20	82	31.2/36.8	0–120	0–115	Y	Normal preoperative/ postoperative	Grade III
28	12	N	0	20	72	30.3/47.4	0–95	0–135	Y	Normal preoperative/ postoperative	Normal
29	15	SCAR	2	15	50	25.8/23.6	0–80	0–130	N	—	Normal
30	12	N	0	25	96	45.6/62.2	0–130	0–130	N	—	Unable to perform
31	12	N	0	25	100	56.4/55.7	0–140	0–140	Y	Normal preoperative/ postoperative	Normal
32	12	N	0	25	100	41.9/63.4	0–140	0–140	Y	Normal preoperative/ postoperative	Normal
33	16	N	0	20	90	42.4/31.5	0–140	0–140	Y	Normal preoperative/ postoperative	Normal
34	37	N	0	25	100	47.2/61.5	0–125	0–125	N	—	Normal
35	36	N	0	25	90	23.5/49.2	0–140	0–140	Y	Normal preoperative/ postoperative	Unable to perform
36	36	N	0	25	95	24.7/48.6	0–140	0–140	Y	Normal preoperative/ postoperative	Unable to perform
37	12	N	0	25	86	50.6/50.2	0–115	0–115	N	—	Preexisting OA

MJL, medial joint line; N, no; OA, osteoarthritis; SF-36 P/M, SF-36 physical component and mental component; VAS, Visual Analog Scale; Y, yes.

At each visit, an independent research nurse documented ROM of both knees using a goniometer and quadriceps strength manually.[14] Postoperative function was determined using 2 validated outcome tools, the general SF-36 and the knee specific Lysholm score.[15] The SF-36 is a generic validated functional outcome measure designed to offer both mental and physical well-being scores compared with a general population. Originally designed for assessment of ligament injuries of the knee, the Lysholm knee score has also been validated for the evaluation of patients with chondral disorders of the knee and those with an acute patellar dislocation. It is a condition-specific 100-point outcome score that contains 8 domains: limp, locking, pain, stair climbing, use of supports, instability, swelling, and squatting (95–100 excellent, 84–94 good, 65–83 fair, and <65 points, a poor outcome).

The research nurse monitored the patient as they filled out a validated visual analog pain score (VAS) and as the patient recorded the location of the knee pain they were experiencing on a knee diagram (Fig. 2). Magnetic resonance imaging (MRI) of the knee was performed on all patients 1 year postoperatively. The MRI scans were reviewed by a fellowship-trained musculoskeletal radiologist, with particular attention paid to whether or not there were PF cartilage changes on the STIR and T2 gradient echo sequences and any other radiographic evidence of detrimental effects to the structures of the knee joint attributable to the surgical technique (Table 2).

Technique

The patient is brought to the operating room and placed supine. The leg is prepped and draped in the usual manner.

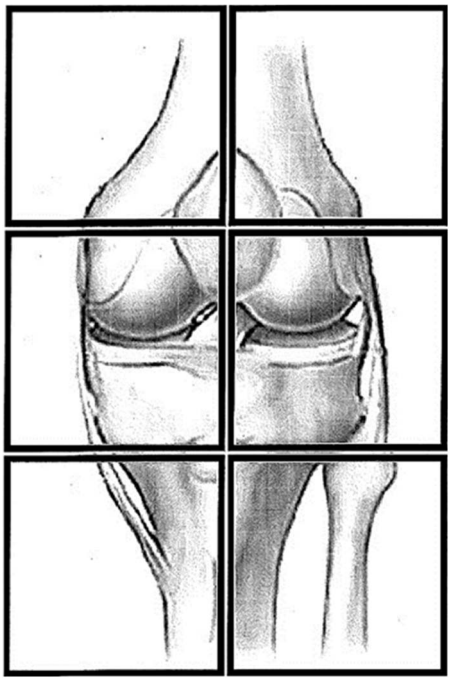

FIGURE 2. Knee pain diagram for documentation of location of pain.

Tourniquet is applied and inflated based on surgeon preference (350 mm Hg). Open wounds are managed as per standard protocols. A bolster is placed under the knee to obtain slight knee flexion and to raise the leg just above the contralateral limb so that lateral fluoroscopic views are easily obtained (see **Video 1**, **Supplemental Digital Content 1**, http://links.lww.com/BOT/A135).

A 2.5- to 3.5-cm incision is made approximately 2.5 cm proximal to the proximal pole of the patella using a #10 blade. This is taken through the skin and quadriceps tendon directly down to the anterior femur. If the tourniquet is not inflated, electrocautery is used as needed to control bleeding. Thereafter, using the surgeon's index finger or a blunt periosteal dissector, the PF joint is entered directly under the proximal pole of the patella. If the patella is easily maneuvered using the index finger (loose PF), the cannula is then inserted. If there is pressure on the surgeon's index finger during the maneuver (tight PF), consideration is taken to extend the incision distally several centimeters in a lateral parapatellar direction before inserting the cannula system. The cannula, once inserted, acts as a percutaneous portal to perform the entire procedure of canal preparation and nail insertion.

The cannula and trocar are then inserted into the knee, with the cannula sliding down the trochlear groove until it comes into contact with the anterior tibia at the junction of the anterior cortex and articular surface. To prevent any movement of the cannula, it should be secured to the femur using a guide pin through one of the available portals placed proximally in the cannula by the manufacturers for this purpose. The blunt trocar is then exchanged for a multiholed guide pin sleeve. A 3.2-mm guide pin is placed into the central hole and drilled into the tibia just until minimal purchase is achieved (~3–5 cm). An AP, followed by a lateral fluoroscopic view, is then obtained to determine position of the guide pin. The appropriate position should be just medial to the lateral tibial spine and in line with the tibial shaft on the AP view and at the junction of the anterior cortex and the articular surface on the lateral fluoroscopic view. If the pin is angled (varus/valgus) on the AP view, the pin should be redirected. If the pin is incorrectly positioned on the lateral, the bolster should simply be moved proximally or distally to alter the amount of flexion/extension of the knee to correct the pin's trajectory.

The pin is simply a point of purchase. It should not be drilled in farther than 3–5 cm. The reason for this is that the surgeon should be able to direct the subsequent reaming. If the pin is advanced too far down the shaft initially, it is no longer a guide but rather acts as a monorail, forcing the reamer to follow its path, preventing the surgeon to correct any malposition that may occur.

Once the guide pin position has been accepted, the multihole sleeve is removed and an entry reamer is introduced through the cannula to open the canal. As stated previously, the surgeon should direct the reamer to assure proper placement. Typically, this is verified by inserting the reamer 1–2 cm and checking position first on the AP view. If acceptable, the fluoroscope is shifted to the lateral position and the reamer is advanced under direct visualization using multiple spot views.

The reamer should not be introduced across the fracture unless the fracture is reduced. If reduction is required, then the reamer is removed and a reduction tool is inserted through the cannula to reduce the fracture. Because the leg is essentially flat on the operating table, gravity is not an issue, and the fracture can be easily reduced and/or held by an assistant while the reduction tool is used and reduction achieved. If the fracture is highly comminuted, reduction forceps, clamps, blocking screws, etc, can be used easily to assist the reduction. Once the fracture is reduced (by whatever means), a straight guide wire is placed. Nail length is determined using a specially designed ruler through the cannula.

Intramedullary reaming is then performed 1.5–2 mm beyond the chosen nail diameter (Fig. 3) and the properly selected nail is inserted (Fig. 4). Because the leg is in extension, an assistant should hold the heel and apply resistance against the insertional force occurring during nail placement. Both the AP and the lateral alignment must be monitored during nail placement. Nail passage through the fracture, distal positioning, and proximal seating are all best seen on the lateral fluoroscopic view, which can easily be obtained due to the fact that the leg is in extension. Similarly, because the leg is in extension, step stools for the surgeon are not required, and it is highly unlikely that the guide wire, reamers, or drill, will become contaminated.

Once seated, positioning of the leg in extension allows simple AP and lateral views. Proximal locking screws are inserted followed by distal interlocks. If compression of the fracture is desired, distal locking is performed first. This is then followed either with a "back-slapping" technique or the use of compression screws (if built into the nail). After final fluoroscopic views are obtained, the cannula is removed, and the knee is washed with saline. A full ROM should be applied to the knee for verification of patella tracking, and the wounds are then closed in a layered manner. If the simple percutaneous incision without parapatellar extension is used, skin closure alone suffices. If a parapatellar extension is performed, this should be repaired using interrupted resorbable sutures.

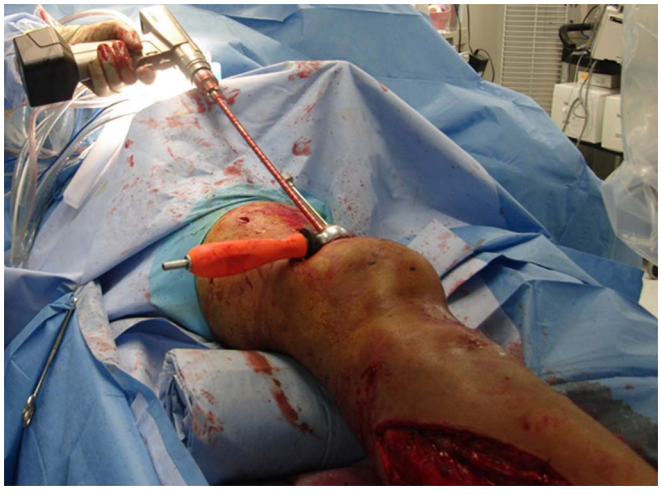

FIGURE 3. Reaming the tibia through a PQ portal. Note the semiextended position with the knee over a small bolster.

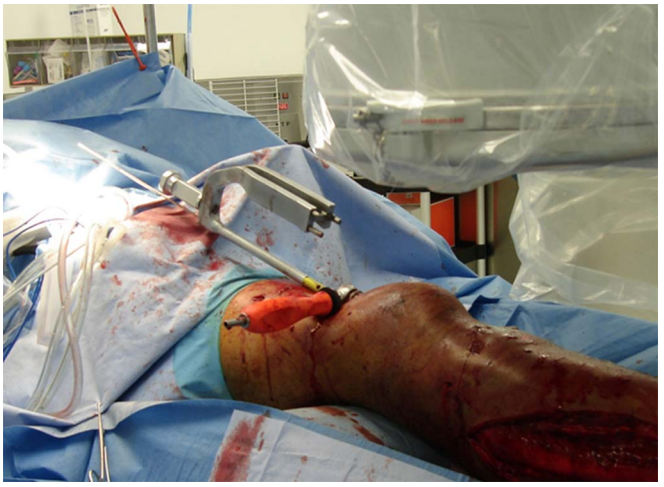

FIGURE 4. Insertion of nail through protective cannula. Note the length of nail insertion device to slide nail through cannula.

Study Support

This study was approved by institutional review board. Arthroscopy was not billed because it was considered part of the procedure. MRI scans and any out of the ordinary costs were supplied by a grant from the Tampa General Foundation. Additional instruments required for the study were supplied from a grant by the respective manufacturers (Stryker Orthopaedics; Smith and Nephew).

RESULTS

Patients and Fractures

Of the 56 fractures (55 patients), 10 fractures (10 patients) were lost to follow-up. Of the remaining 46 fractures, 4 patients with 4 associated tibial plateau fractures and 1 patient with associated severe pilon, talus, and calcaneal fractures were excluded (due to severe intra-articular involvement) secondary to articular fracture plating in addition to the IMN. Four of the remaining fractures (4 patients) were treated in the early part of the evaluation as part of a quality assessment of the technique and were not part of the prospective study. They were excluded. Therefore, 37 fractures (36 patients) met criteria with a minimum of 1-year follow-up (range: 12–49 months, average F/U = 18.5 months). There were 23 males and 13 females. Average age was 41.17 years (range: 18–76 years). Seven patients sustained multisystem injuries (19.4%). Fifteen fractures were open and 22 were closed. Fractures included 14 OTA 42A (A.1 = 1, A.2 = 9, and A.3 = 4), 14 42B (B.1 = 5, B.2 = 6, and B.3 = 3), and 9 42C (C.1 = 1, C.2 = 5, and C.3 = 3). Of these, 7 were in the proximal-middle region, 16 in the middle, and 14 in the distal-middle region. Nine (9/14 = 64.3%) of the distal-middle fractures required additional fixation before nail insertion. Specifically, 4 required AP lag screws to secure a nondisplaced coronal split fracture, 4 were additionally treated with fibula fixation, and 1 required both AP lag screws and additional fibula fixation. There were 19 Trigen Meta Nails (Smith and Nephew) and 18 Stryker T2 Nails (Stryker Orthopaedics) used.

Limited arthroscopy was employed to evaluate the PF joint alone in 40.5% (15/37) of the cases.

Fracture Healing

At the 1-year evaluation, all but one fracture had healed (97.3%), and all but two open fractures had uneventful healing. These 2 open fractures were treated with the Masquelet technique, with 1 completing treatment with antibiotic impregnated cement exchange and healing (RUST score = 12) after Reamer/Irrigator/Aspirator (RIA) grafting.[16,17] Although scheduled for a RIA bone graft, the second patient (#24) declined because he was asymptomatic in that limb. Radiographs revealed excessive heterotopic ossification (probably secondary to his closed head injury), and a synostosis between the tibia and fibula with incomplete healing around the anterior and medial aspect of the spacer (RUST score = 8) (Figs. 5, 6). Five legs (13.5%) required proximal screw removal after the fracture had healed for pain, with one of these having distal screws removed as well (Fig. 7). There were no instances of heterotopic ossification or loose bodies in the knee based on arthroscopy, radiographs, and MRI scans. Only 1 fracture had an angular deformity (2.4%). This was an isolated proximal-middle fracture that had a blocking screw placed to secure an anatomic reduction as seen on the postoperative x-rays (Fig. 8). During the healing period, this fracture settled and healed with both a procurvatum (10 degrees) and a varus (5 degrees) deformity. At last follow-up (37 months), the patient (#34) had excellent scores, was not symptomatic, and declined a corrective osteotomy.

Knee ROM

Mean arc of knee motion was 124.4 degrees for the affected extremity compared with 127.2 degrees for the contralateral knee. Thirty-six knees had full extension while the remaining one was within 5 degrees of full extension (≤5 degrees to full EX = 100%). Thirty knees had either flexion ≥120 degrees or flexion equal to the opposite knee, with an additional 2 within 5 degrees to full flexion (≤5 degrees to full FLEX = 86.5%). Of the remaining 5 knees, 2 knees had decreased flexion to 110 degrees, both were in multiply injured patients (#17, 18). One of these was the knee that had 5 degrees loss to full extension: the "normal" knee had a ROM of 20–75 degrees. Of the remaining 3, flexion ranged from 105 to 95 and 80. One knee was in a patient with a preexisting stroke on the contralateral side. Flexion was functional (≥90) in all but one knee (97.3%). The patient with flexion to only 80 degrees, was unfunded and had pain issues, and needed but could not afford, physical therapy to improve her function. Quadriceps strength as measured manually was equal at 1 year in all but these latter 2 patients (#28, 29).

Knee Pain

Patients were counseled that the VAS question was specific to the PF, anterior distal thigh, and anterior proximal tibial region of the knee. When they were asked to respond the question, "On a scale of 0-10 with 10 being the worst, how would you rate the pain in your knee, and only your knee?" 35 of 36 patients (97.2%) documented no pain (VAS = 0). One patient (#29) did complain of mild pain (VAS = 2) at the SP incision site (this was the same patient with the pain and financial issues, see above), and this was confirmed when they filled out their pain drawings. No patient complained of pain at the anterior knee/patellar tendon region. Three patients (8%) complained of pain at the medial knee: this correlated with the medial joint line on pain drawings. Two had known meniscal tears and degenerative arthritis with reported joint line pain well documented and present before1 the injury (#9, 17). The final one (#11) was in a severely polytraumatized patient, whose MRI was normal.

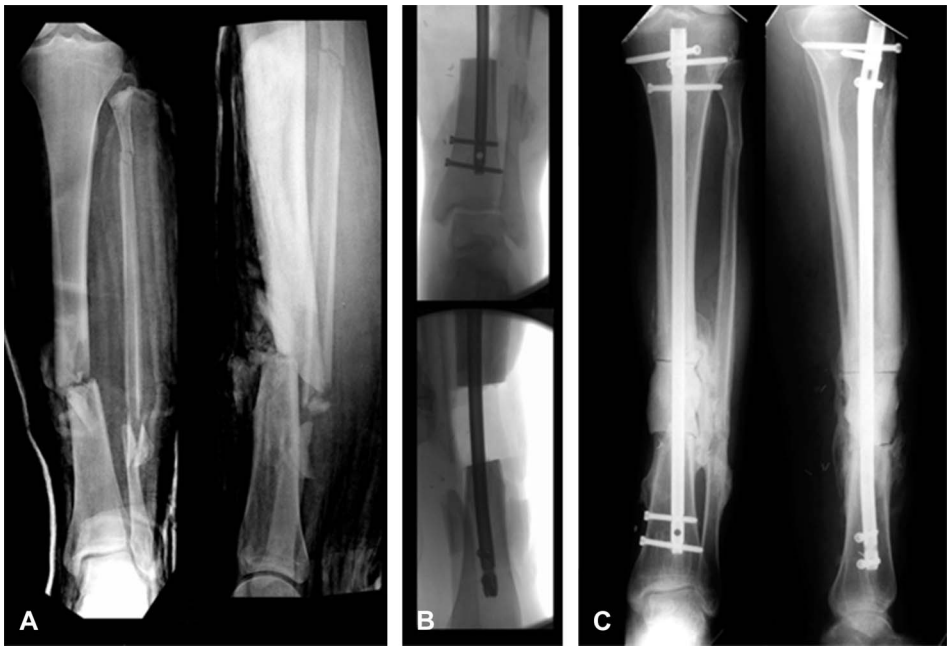

FIGURE 5. A, Open fracture, OTA 42C.3, middle type (#24). B, Treated with resection, IMN via a SP portal, and cement spacer to begin masquelet technique. C, Returned at a year declining further treatment. Radiographs revealed heterotopic ossification resulting in healing about spacer.

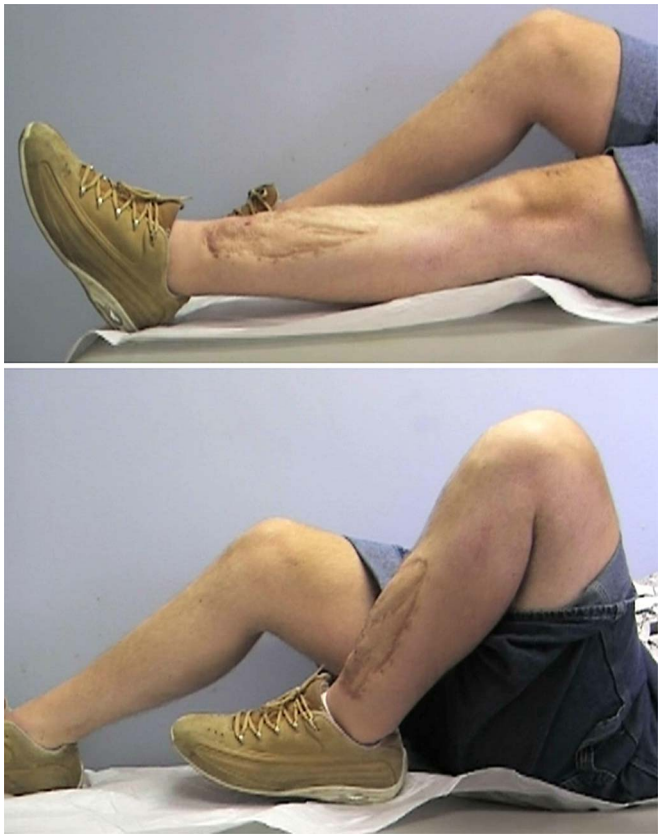

FIGURE 6. Same patient (#24), full ROM 0–130 degrees. Note that the other leg has lost 40 degrees of extension.

Patients did, however, complain of residual pain secondary to prominent locking/blocking screws, scars from open wounds, fasciotomies, soft tissue flaps, or the fracture site itself (Figs. 9, 10). When asked about pain as part of the Lysholm score, 21 patients exhibited no pain (25/25), whereas 8 patients exhibited slight pain during athletics (20/25). Of the 7 patients with a Lysholm pain score of ≤15 of 25, all were related to either their injury or the preexisting conditions (vide infra).

Functional Outcome Scores

The Lysholm score was used to assess overall knee function (37 knees) as it related to gait, stair climbing, and walking/running. The mean Lysholm knee score was 82.14. The breakdown was as follows: 14 excellent, 8 good, 7 fair, and 8 poor. Of the 8 poor results (8 knees), all had complaints related to prolonged walking/running and stair climbing. Four of these patients suffered from polytrauma and 1 from preexisting arthritis and could not separate out their limitations when filling out the questionnaire. Mean SF-36 physical and mental scores were 41.8 and 47.9, respectively.

Evaluation of the PF Joint

In those patients undergoing an arthroscopic assessment of the PF joint prenail and postnail insertion, no cartilage changes, gouges, or pressure changes from the cannula were seen in 13 of 15 patients (86.7%) (Fig. 11). Two knees showed evidence of grade II chondromalacia limited to the trochlea groove immediately after completion of the procedure as seen on arthroscopic images. Thirty-three of 37 knees had an MRI scan performed at the 1-year follow-up. One patient (1 fracture) refused the scan and 3 patients (3 fractures) could not undergo the test secondary to metallic implants elsewhere. Of the remaining 33 MRI scans, 1 patient had grade II PF changes and 1 had grade III PF changes. For the patients that had an arthroscopic evaluation of their PF joint, there was no relationship between the arthroscopic findings and MRI findings. The 2 cases exhibiting arthroscopic grade II changes in the PF joint immediately postoperatively were read as normal on their 1-year MRI scan. Both had a Lysholm score of 100

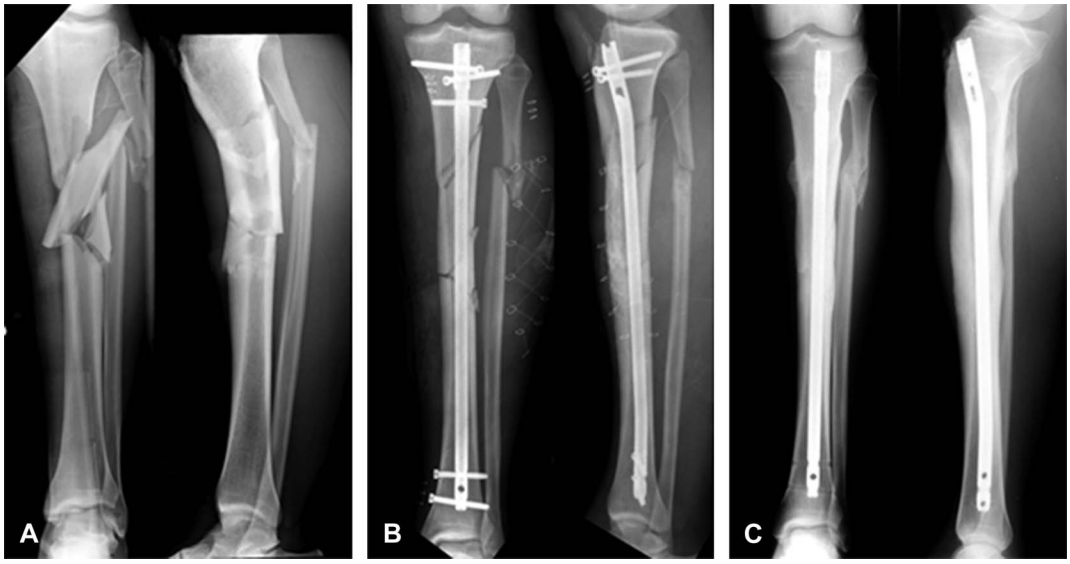

FIGURE 7. A, Comminuted proximal-middle + middle fracture (OTA 42C.2) in a polytrauma patient (#4). B, Immediately after the index procedure. C, One year postoperatively after the screw removal secondary to pain at screw heads.

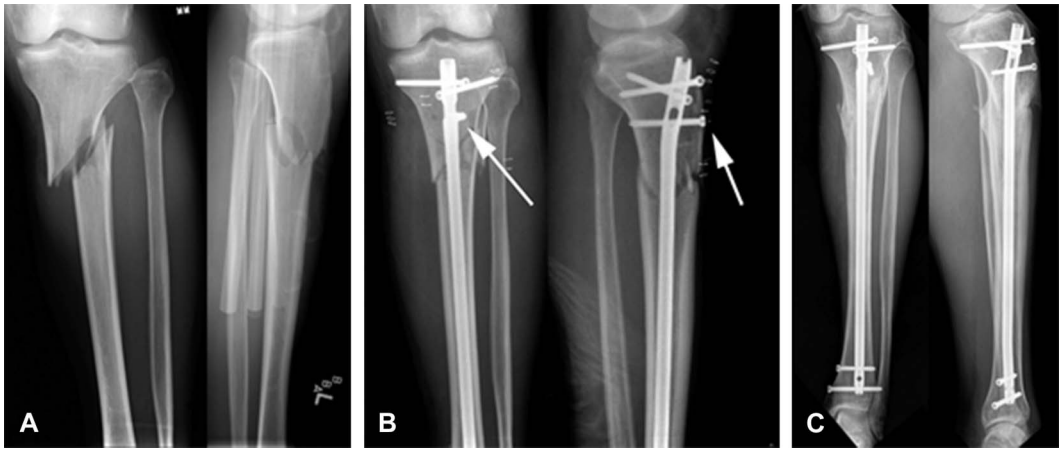

FIGURE 8. A, Simple proximal-middle oblique fracture (#34). B, Postoperative x-rays showing anatomic reduction with use of a lateral blocking screw (arrows). C, One-year follow-up with settling and radiographic varus and procurvatum. This did not affect the clinical outcome and the patient refused the offered osteotomy.

and a 0 VAS. Conversely, 1 case with positive MRI findings had completely normal pre- and postoperative arthroscopic findings. Only 1 case, that did not have an arthroscopy, had an MRI that was read as grade II chondromalacia. Finally, none of the arthroscopic or MRI findings correlated with the clinical examination except for those patients with meniscal pathology or preexisting osteoarthritis.

DISCUSSION

The semiextended approach for IMN of the tibia was originally described by Tornetta et al.[9,18] This technique requires a large parapatellar incision to reflect the patella to place the IMN in the trochlea groove. The technique is particularly useful when treating difficult metaphyseal and metadiaphyseal proximal and distal tibia fractures, where the amount of knee flexion required in traditional approaches causes much difficulty in obtaining and maintaining an acceptable reduction.

The use of a SP portal adds a novel percutaneous component to the semiextended approach. It is our understanding that Dr Dean Cole originally developed and used this approach in a large series of patients with proximal tibial fractures (personal communication). To our knowledge, however, there have been no published reports on the clinical use of this portal, despite much anecdotal and cadaveric evidence that it is safe and useful.[19–21] One of the critical points of controversy surrounding this technique is the concern for adverse effects on the PF articulation. At 1 year, based on our follow-up data, there seems to be no deleterious effect to the PF joint when this portal and technique are used correctly. Only one of the MRI scans performed at 1 year demonstrated mild cartilage changes (outerbridge II) in the PF joint. Additionally, 2 knees had arthroscopic images that revealed similarly mild cartilage injury postoperatively, but neither correlated with their 1 year MRI, which was read as normal. Importantly, in none of these 3 instances, did any of these findings correlate with the clinical examination at 1 year. Finally, knee ROM was painless and functional in all but

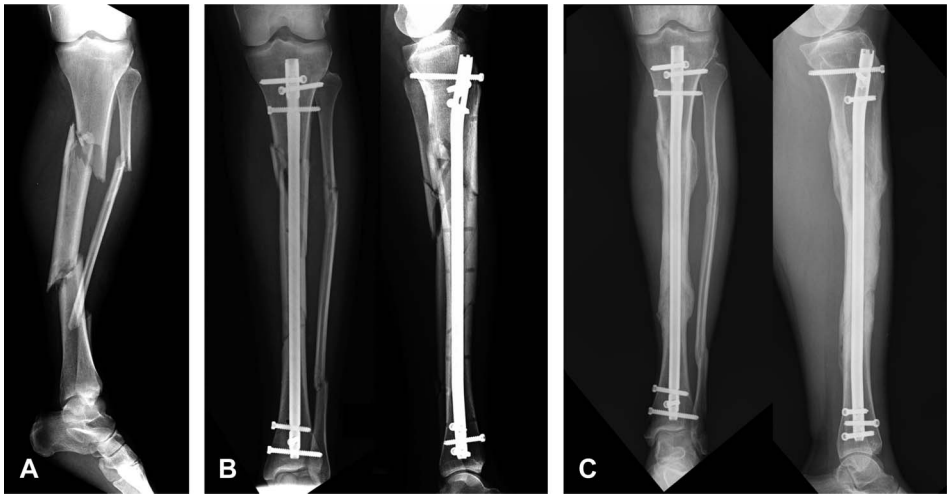

FIGURE 9. A, Polytrauma patient with proximal-middle + middle (OTA 42C.2.2) fracture (#3). B, After the index procedure. C, Healed at 1 year.

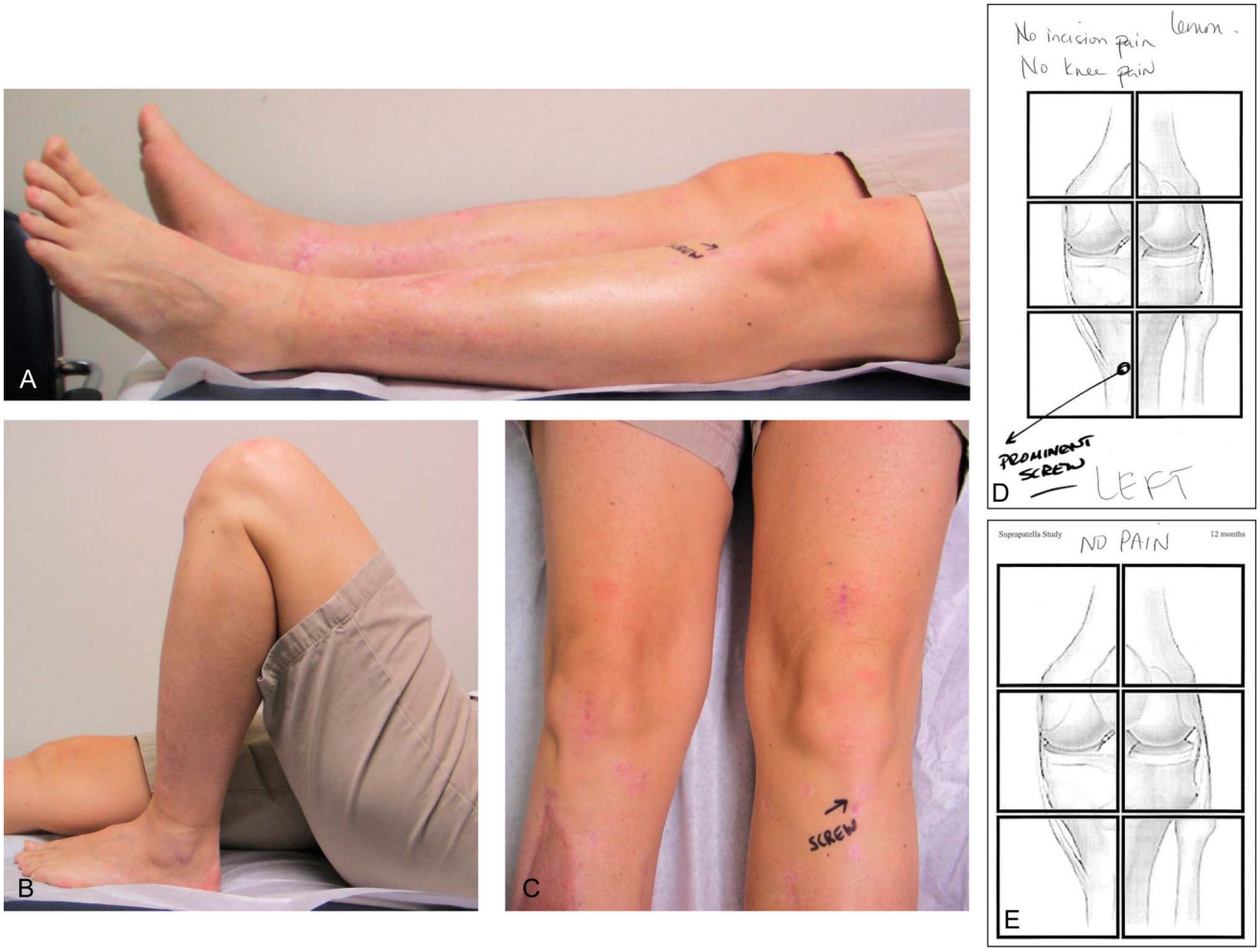

FIGURE 10. A, B, Same patient (#3) with full ROM knee at 6 months. C, Only initial complaints were related to a painful screw head (D). Pain drawing at 6 months. E, Screw removal was declined secondary to resolution of symptoms, and pain drawing was negative at 12 months.

two knees when compared with the normal contralateral side. Clearly, these patients will need to be followed at a minimum of 2–5 years to document any late effects that may occur, but the 1-year outcomes seem promising in this regard.

It is even more remarkable that none of our SP portal patients complained of any PF or anterior knee pain whatsoever. The reasons are unknown, but in patients with traditional nail insertion techniques, it may be that the patella tendon and the soft tissue surrounding that tendon simply do not respond well to open manipulation.[22,23] Vaisto et al noted that differing the traditional approach (paratendinous vs. transtendinous) made no difference when evaluating the cause of anterior knee pain after IMN.[24] Interestingly, retrograde femoral IMN patients do not seem to complain about knee pain using essentially the same standard inferior patella tendon approach, but a different bone window. Furthermore, because the bone window for tibial nail insertion remains the same whether a standard or SP portal is used, the difference may simply be the prolonged knee flexion associated with tibial nail insertion in contrast to both the semiextended tibial and retrograde femoral nail insertion method, where the knee is largely in extension.[19] It is possible that using a percutaneous portal proximal to the patella avoids the patella tendon altogether and therefore, the associated pain. When comparing our study to other reports that describe pain in the leg after injury and IMN insertion, it must be stated that our evaluation was specifically focused on whether the portal and/or the technique caused knee pain and not generalized leg pain, which in the trauma patient, and in our patients, is multifactorial. Whatever the reason, the fact that none of the patients experienced any PF or anterior knee pain at all is remarkable. A larger study population will be necessary, however, before definitive comments about lack of knee pain can be stated with certainty.

Although our patients did not experience any heterotopic ossification or joint mice as a result of the procedure, concerns arise regarding reaming debris as well. Again the literature for retrograde nailing is illuminating. Despite the thousands of retrograde nails placed because the technique became popular

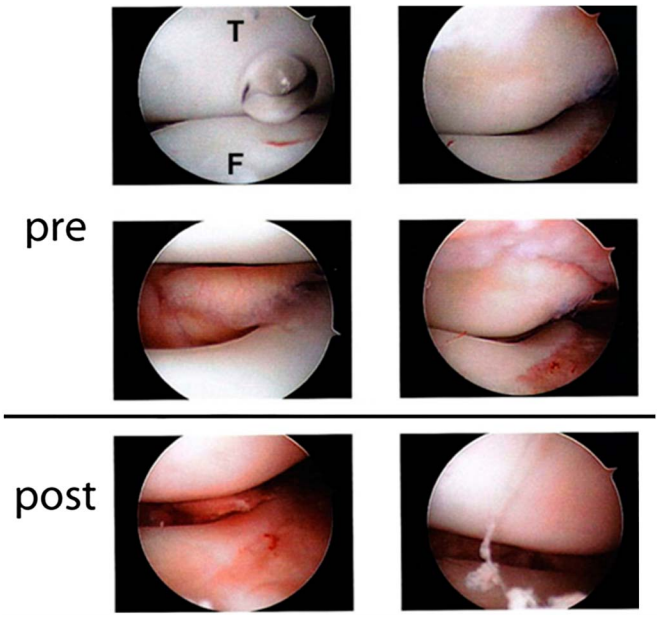

FIGURE 11. Pre- and postnailing arthroscopic findings (#32). Note the patella (P) and trochlea groove of femur (F).

in the 1990s, and the scores of papers verifying the technique's results, there has been only 1 case report of heterotrophic ossification occurring in the knee joint as a result of retrograde nailing of the femur.[25] We believe that this is because bone debris cannot typically form new bone in synovial fluid. As a result, although it is imperative to wash the knee joint after removal of the cannula, this issue seems not be a continued concern.

One of the limitations of this study was the late addition of arthroscopy to evaluate macroscopic cartilage injury of the PF joint at the time of the index procedure. Although the results clearly show no immediate cartilage injury, and these data correlated with the MRI scan results at 1 year after the index procedure, the fact that arthroscopy was only performed in half of the cases, should leave questions in the reader's mind.

In conclusion, this is the first paper to critically document clinical and radiographic results using the percutaneous SP portal for the semiextended approach for IMN of the tibia. Our 1-year results indicate that the procedure resulted in excellent tibial alignment, union, knee ROM, with no apparent sequelae in the PF joint based on immediate arthroscopy and 1-year MRI scans. Even more interesting was the absence of anterior tibial pain typically found in up to 25%–60% of cases where a tibial nail is inserted in a standard fashion.[22] We are presently completing an OTA approved and funded RCT study prospectively evaluating standard nail insertion to semiextended nail insertion using a SP portal. This study includes arthroscopy in all cases using a SP portal. These results will be published in the future.

REFERENCES

1. Bohler L. *Medullary Nailing of Kuntscher*. 1st ed. Baltimore, MD: Williams and Wilkins; 1948.
2. Bone LB, Johnson KD. Treatment of tibial fractures by reaming and intramedullary nailing. *J Bone Joint Surg Am.* 1986;68:877–887.
3. Weller S, Kuner E, Schweikert CH. Medullary nailing according to Swiss study group principles. *Clin Orthop Relat Res.* 1979;138:45–55.
4. Lottes JO. Medullary nailing of the tibia with the triflanged nail. *Clin Orthop.* 1974;105:253–266.
5. Freedman EL, Johnson EE. Radiographic analysis of tibial fracture malalignment following intramedullary nailing. *Clin Orthop Relat Res.* 1995;315:25–33.
6. Krettek C, Miclau T, Schandelmaier P, et al. The mechanical effect of blocking screws ("Poller screws") in stabilizing tibia fractures with short proximal or distal fragments after insertion of small-diameter intramedullary nails. *J Orthop Trauma.* 1999;13:550–553.
7. Josten C, Marquass B, Schwarz C, et al. Intramedullary nailing of proximal tibial fractures. Complications and risk factors. *Unfallchirurg*. 2010; 113:21–28.
8. Ricci WM, O'Boyle M, Borrelli J, et al. Fractures of the proximal third of the tibial shaft treated with intramedullary nails and blocking screws. *J Orthop Trauma.* 2001;15:264–270.
9. Tornetta P III, Riina J, Geller J, et al. Intraarticular anatomic risks of tibial nailing. *J Orthop Trauma.* 1999;13:247–251.
10. Cole JD. A suprapatellar portal for tibial nail insertion. 2006.
11. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium—2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007;21:S1–S133.
12. Schemitsch EH, Bhandari M, Guyatt G, et al. Prognostic factors for predicting outcomes after intramedullary nailing of the tibia. *J Bone Joint Surg Am.* 2012;94:1786–1793.
13. Kooistra BW, Dijkman BG, Busse JW, et al. The radiographic union scale in tibial fractures: reliability and validity. *J Orthop Trauma.* 2010; 24(suppl 1):S81–S86.
14. Sarwark JF. *Essentials of Musculoskeletal Care*. 4th ed. Sarwark JF. Chicago, IL: American Academy of Orthopaedic Surgery; 2010.
15. Collins NJ, Misra D, Felson DT, et al. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). *Arthritis Care Res (Hoboken).* 2011;63(suppl 11):S208–S228.
16. Masquelet AC, Fitoussi F, Begue T, et al. Reconstruction of the long bones by the induced membrane and spongy autograft. *Ann Chir Plast Esthet.* 2000;45:346–353.
17. Sagi HC, Young ML, Gerstenfeld L, et al. Qualitative and quantitative differences between bone graft obtained from the medullary canal (with a Reamer/Irrigator/Aspirator) and the iliac crest of the same patient. *J Bone Joint Surg Am.* 2012;94:2128–2135.
18. Tornetta P III, Collins E. Semiextended position of intramedullary nailing of the proximal tibia. *Clin Orthop.* 1996;328:185–189.
19. Gelbke MK, Coombs D, Powell S, et al. Suprapatellar versus infrapatellar intramedullary nail insertion of the tibia: a cadaveric model for comparison of patellofemoral contact pressures and forces. *J Orthop Trauma.* 2010;24:665–671.
20. Eastman J, Tseng S, Lo E, et al. Retropatellar technique for intramedullary nailing of proximal tibia fractures: a cadaveric assessment. *J Orthop Trauma.* 2010;24:672–676.
21. Eastman JG, Tseng SS, Lee MA, et al. The retropatellar portal as an alternative site for tibial nail insertion: a cadaveric study. *J Orthop Trauma.* 2010;24:659–664.
22. Keating JF, Orfaly R, O'Brien PJ. Knee pain after tibial nailing. *J Orthop Trauma.* 1997;11:10–13.
23. Keating JF. Invited commentary: anterior knee pain after intramedullary nailing of the tibia: biomechanical effects of the nail entry zone and anterior cortical bone loss. *J Orthop Trauma.* 2013;27:41–42.
24. Vaisto O, Toivanen J, Paakkala T, et al. Anterior knee pain after intramedullary nailing of a tibial shaft fracture: an ultrasound study of the patellar tendons of 36 patients. *J Orthop Trauma.* 2005;19:311–316.
25. Takemoto RC, Epstein D, McLaurin TM. Intra- and periarticular heterotopic ossification in the knee after a low-velocity gunshot wound treated with retrograde intramedullary nailing of the femur. *J Orthop Trauma.* 2011;25:e77–e82.