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Intramedullary tibial nailing: percutaneous suprapatellar approach with the knee in semi-extended position and the EstreMO nail. The Italian contribution

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Summary

The management of closed mid shaft tibia fractures remains reamed intramedullary statically locked nailing [1,2]. Since the first description of intramedullary tibia nails by Gerhard Küntscher [3,4] and through the subsequent introduction of the locked nails by Grosse and colleagues [5,6], infrapatellar and parapatellar access routes have been utilized. The discussion on the correlation between different entry points and the incidence of anterior knee pain has been extensive [7-10]. Nailing of a proximal tibia fracture can be complicated by malalignment, typically an apex anterior with valgus angulation, coupled with posterior displacement of the distal fragment [11]. The insertion of an intramedullary nail in the tibia utilizing a suprapatellar percutaneous entry point, with the knee in semi extension, appears to mitigate the establishment of malreduction [12,13]. Because the suprapatellar route does not interfere with the patellar tendon, it consequently appears to lead to reduced incidence of knee pain and rapid rehabilitation. Originally indicated for proximal tibia fractures, this modification of the classical tibial nailing has been proven effective in all tibial fracture locations. It allows for fast setup of the operating room, with the patient in a supine position on a translucent table. It simplifies the treatment in polytrauma patients with injuries to the soft tissue surrounding the patellar tendon area fractures. It is coupled by excellent and unobstructed intra-operative radiological projections, allowing the maintenance of fracture reduction with minimal manual longitudinal traction and/or percutaneous clamps. Furthermore, the implementation of a reamed, locked intramedullary nail with no Herzog curve, designed specifically for the suprapatellar insertion, with ad hoc instrumentation, cannulas, and trochars, allowing protected passage under the patella in the trochlear femoral groove, is paramount in the nailing of proximal, mid-diaphyseal and distal tibial fractures.

Key words: intramedullary, suprapatellar, tibia fracture

Introduction

The treatment of choice for unstable and displaced tibial shaft fractures in the adult remains reamed intramedullary locked tibia nailing: the goals are to restore length, alignment, and rotation of the fractured tibia, achieving bone union with minimal surgical dissection. The surgical implant offers appropriate biomechanical fracture stabilization and acts as a load-sharing device allowing for early post-operative mobilization and weight bearing. Recent advances in nail design and reduction techniques have expanded the indications for intramedullary nail fixation to include proximal and distal third tibial fractures. Intramedullary nail fixation represents a well-described and universally performed surgical procedure for the community orthopedic surgeon as well as dedicated orthopedic trauma surgeon. The surgical technique continues to evolve, and numerous recent investigations have contributed significant advances in this area [14-19]. The goal of this article is to describe the current concepts of intramedullary nail fixation of tibial shaft fractures and the recent developments in this field.

Historical remarks

Gerhard Küntscher is credited for being the founder of the modern concept of intramedullary fixation of long bone fractures and a gifted developer of intramedullary nails [9]. He initially experimented with a straight, unreamed, V-shaped, stainless steel intramedullary nail in the late 1930s [10-12] and subsequently moved to a cloverleaf pattern to resist torsion. The Küntscher nail relied on a frictional fit between the nail and the bone; he routinely attempted to insert the nail without exposure of the fracture site, with a flexed position of the knee of about 50° and insertion proximal to the tibia tuberosity.

Posterior cortical perforation proved to be a complication with straight Küntscher nails. If the starting point was too anterior on the tibial plateau, it would not place the nail in line with the medullary canal and would abut the posterior cortex, leading to a potential iatrogenic fracture. The proper, far posterior, starting points would risk intra-articular cartilage, ligamentous, and/or meniscal damages. Herzog modified the Küntscher nail by adding a 20° apex posterior curve to the proximal nail at 120 mm from the top and 5° apex posterior curve to the distal nail [13]. This "Herzog curve" allowed for an eccentric anterior starting point on the tibial cortex between the tibial tubercle and the plateau, avoiding insertion through articular cartilage. The potential disadvantage of posterior fracture misplacement due to the wedge effect of the curve at or below the fracture site resulted in a further modified Herzog curve of 10° more proximal at 50 mm from the top. Advancements in radiographic image intensifiers in the late 1960s, the advent of motorized reamers, and the increased complication rate that accompanied the advent of compression plating for tibias and femurs in the 1960s, quickly contributed, in the 1970s, to a renewed interest in refining closed nailing techniques. Because intramedullary nailing of the tibia offered poor fixation in the upper and lower ends of the bone [13], Grosse and Kempf added interlocking screws that could be inserted through the bone and nail, above and below the fracture site [20-23]. These locking screws prevented rotational movement and telescoping, adding fracture stability and allowing earlier motion and weight-bearing. Interlocking nails also extended the indications for nailing to include proximal and distal fractures as well as comminuted and segmental fractures [23-26]. Interlocking nails had either dynamic holes, which allowed for controlled fracture compression during weight-bearing, or static holes, which offered greater stability but no compression [25]. The Grosse-Kempf nail employed the Herzog curve proximally and the approach starting point was unchanged. However, the longitudinal slot in the tubular universal nail resulted in decreased rotational stiffness, with potential rotational instability, especially with small diameter intramedullary nails. To obviate this problem, a closed section nail was designed and popularized by Russell and Taylor in the late 1980s [26]. Until then, tibia intramedullary nails were still largely inserted using traction fracture tables with the patient's hip and knee flexed and a padded bolster placed beneath the popliteal fossa. Traction was applied using a calcaneal pin or foot holder. With the advent of locking screws, the fracture table setup created potential difficulties with the radiographic visualization of the distal target. Even "free hand" techniques, popular in North America, had difficulties when attempting to place the locking screws. The solution was to abandon the traction devices to avoid the cumbersome traction holder. To do this, surgeons would hang the leg off a regular tower table with gravity providing the traction force. An assistant would hold the tibia, while squatting, until the nail had traversed the fracture site. The distal end of the surgical table could then be elevated and the locking screws can be inserted. Therefore, this technique was still described as challenging, and exposure for adequate intraoperative radiographs was difficult to achieve. In 1991, Moed and Strom [27] and Shakespeare and Henderson [28] discouraged the use of traction during tibia intramedullary nailing. Their studies of closed reamed tibial shaft fractures demonstrated increased compartment pressures when traction was applied during nailing. These results, along with the difficulties that traction tables posed to insertion of locking screws, contributed to influence most surgeons to abandon the use of skeletal traction when inserting tibial nails.

Surgeons began inserting tibial nails on flat, radiolucent tables with the knee in extreme flexion over a padded bar or radiolucent triangle. The leg would be in the near vertical position with traction applied manually by an assistant pulling down on the foot or with the use of a femoral distractor. In 1996, Tornetta [29] offered a new approach to tibial nailing in proximal fractures, aimed at solving the problem of malalignment for this kind of injuries. He used a semi-extended position of the knee, with an open medial parapatellar arthrotomy, rather than the more common patellar tendon splitting approach, which had the knee flexed > 90°. He noted that knee flexion in proximal fractures led to apex anterior angulation secondary to over pull of the quadriceps muscle. In contrast, the semiextended technique, with the knee positioned in 15° of flexion, relaxed the quadriceps muscle preventing the procurvatum deformity. He also initially utilized a large medial incision from the upper pole of the patella to the tibial tubercle, with a medial parapatellar arthrotomy. This open approach allowed direct visualization of the starting point and facilitated lateral patellar subluxation. It utilizes the femoral trochlear groove as a guide to the starting point. This was the first time, in decades, when a series of cases was published using a novel approach to insert a tibial nail. Tornetta and Ryan subsequently revised his semi-extended positioning, from an open approach to one with a minimally invasive 2.5 cm medial incision, proximal to the patella. Cole [30] published his techniques of nailing proximal tibial metaphyseal fractures describing a new approach to nailing, as the classic patellar tendon splitting or medial/lateral parapatellar approaches resulted in unacceptable deformities in proximal one third fractures. He advocated a limited medial parapatellar arthrotomy and retraction of the patella lateral to the femoral sulcus. This technique prevents patellar contact with the nail during introduction, allowing direct insertion into the medullary canal. He also avoids fracture table with distal tibial traction; however, the leg is hung from an overhead chain, attached to a distal femoral traction pin, and employed gravity traction to maintain knee flexion.

In early 2000 the insertion of an intramedullary nail in the tibia, utilizing a suprapatellar percutaneous entry point, with the knee in semi-extension, was introduced to the orthopedic trauma community [11,31,32]. The nails were the conventional IM nails with an added external long inserting device. It appeared to mitigate the establishment of malreduction and demonstrated a reduced incidence of knee pain because the suprapatellar route does not directly interact with the patellar tendon. Originally indicated for proximal tibia fractures, this modification of the classical tibial nailing technique has been shown to be effective in all tibial locations.

In 2016, the EstreMo nail (Citieffe® s.r.l.Italy), a straight closed diameter cannulated titanium tibial nail, exclusively designed for the suprapatellar approach and without an Herzog curve, was initially introduced in the USA. It was the first nail specifically designed for the suprapatellar insertion and coupled with a dedicated instrumentation for the semi-extended position and entry point [33] (Fig. 1A-B).

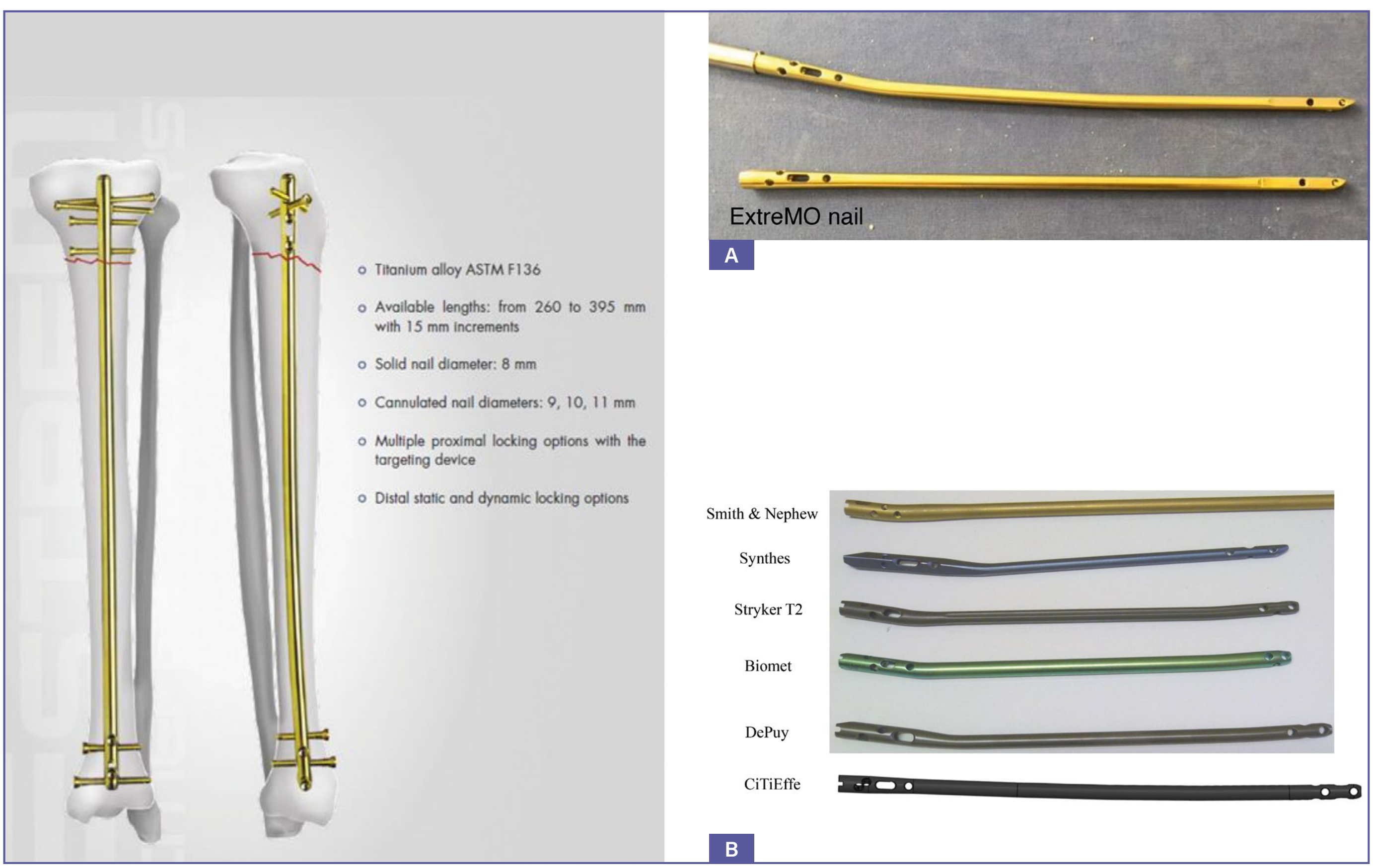

Figure 1. Nail specifically designed for suprapatellar entry point with knee in semiextension. Titanium alloy, cannulated, without Herzog Curve, dedicated ad hoc instrumentation. A) IM Nail designed for SPT insertion, without Herzog Curve; B: examples of intramedullary tibia nails.

Technique: percutaneous suprapatellar approach in semi-extended position

In this approach, the patient is positioned supine on a radiolucent table, with the image intensifier opposite to the surgeon and the video monitor at the foot of the table. The procedure is performed with the knee flexed approximately 15-20°. A bolster is placed under the ipsilateral gluteus to control the rotation of the limb. The senior author (MM) also prefers to use a foam ramp support underneath the leg (Fig. 2). The angle of this leg elevator allows a knee flexion of about 15° to 30°, enough to relax the quadriceps muscle preventing a procurvatum deformity. The device permits a rapid and stable position of the operative leg above the contralateral one, so that the anterior/posterior and lateral C-arm imaging are easily performed and unobstructed. A sterile bump under the knee can be utilized intraoperative, to increase the excursion in flexion-extension, in order to facilitate the introduction of the trochar during the entry point insertion (Fig. 3).

Application of percutaneous reduction clamps, blocking screws, as well as osteosynthesis of fibula or distal tibia can be easily performed in the same setting. Distal locking is also performed with no difficulties because of the stable supine position of the patient coupled with the improved radiographic visualization. The suprapatellar approach in a semi-extended position is also advantageous when distal locking is performed first, allowing for subsequent "back slapping" of the nail to achieve further apposition of the bony fragments when needed to avoid excessive fracture gaps. The senior author has always preferred a minimal transverse skin incision of about 5 cm located two fingerbreadths proximal to the patella (Fig. 4). Such an incision is parallel with the skin creases and minimizes the formation of large scars, particularly in patients prone to develop keloids. The quadricepts tendon is split in a longitudinal fashion (Fig. 5) from the apex of the patella for about 5 cm and then the patellofemoral joint is entered through further blunt dissection. A cannula system with a blunt trochar is then inserted through the patellofemoral joint in order to establish the starting point at the junction of the anterior cortex of the proximal tibia and the articular surface (Fig. 6). If there are difficulties with the insertion of the trochar and cannula at the starting point, just insert the guide pin first and then cannula and trochar over it (Fig. 7). Sometimes, in women and thin patients it is useful to prepare the tract for the operative cannula performing blunt dissection of capsula and retropatellar soft pad. Also, flexion-extension movement of the knee can be utilized to slide the cannula with the trochar under the patella. If the insertion of the cannula-trochar complex has been successful, the 3.2 mm guide pin is then inserted and placed in the starting portal for just a couple of centimeters. A multiholed guide pin sleeve ("honeycomb") is available and may allow for fine adjustments of the starting point, which is generally medial to the lateral intercondylar tibial spine (Fig. 8). Once biplanar C-arm imaging confirms the correct starting point and guide pin alignment with the medullary canal, a rigid entry reamer is advanced over the guide pin, through the entry tube, to a depth of 5 cm

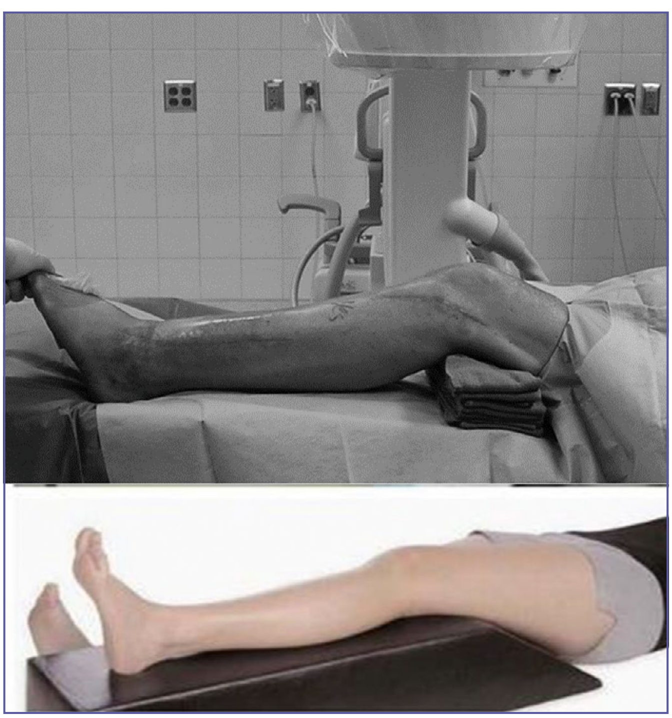

Figure 2. Positioning for a left tibia suprapatellar (SPT) intramedullary nail entry point on a translucent table. Knee in semiextension of 15-20 degrees on towels or foam ramp to maintain the limb above the contralateral for unrestricted xrays images.

Figure 3. Steril bump under the knee intra-operative, to increase flexion of the knee during insertion maneuvers.

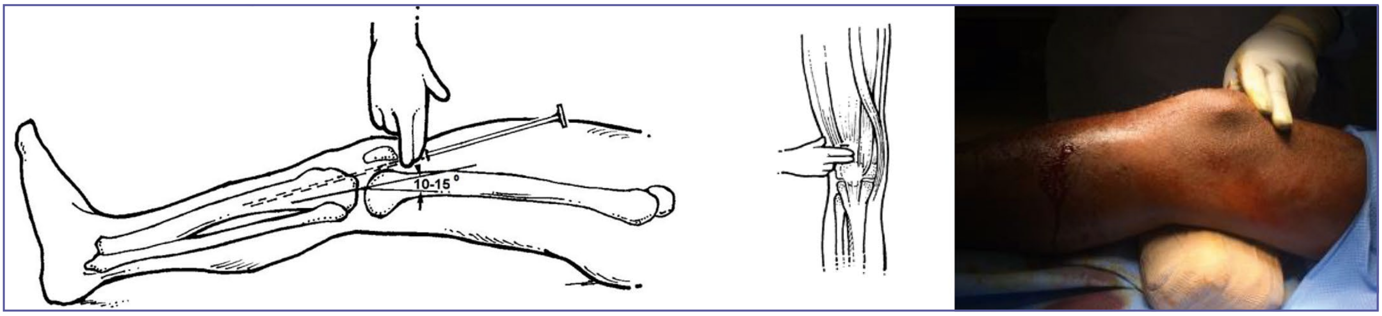

Figure 4. Suprapatellar approach: 5 cm transverse cutaneous incision 2 finger breaths above patella.

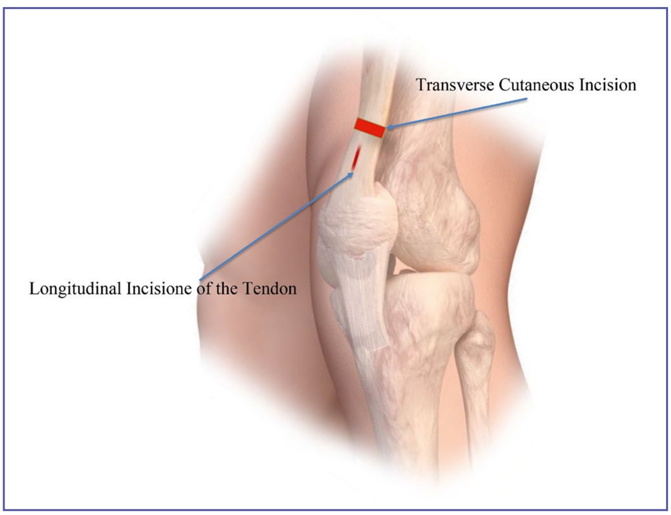

Figure 5. Suprapatellar entry point incisions.

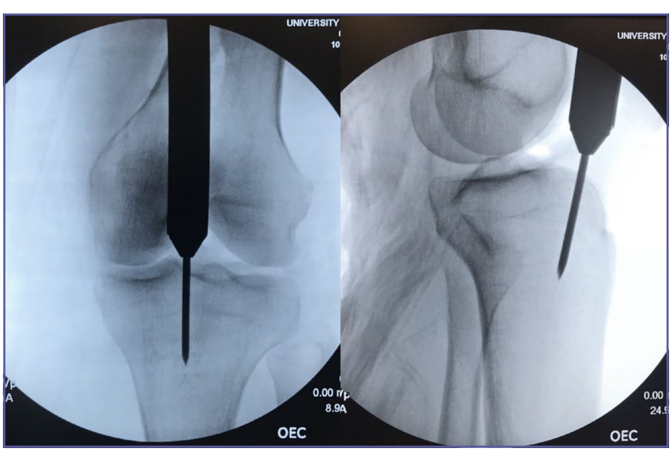

Figure 6. Trochar and sleeve inserted over the guide wire.

in the tibia (Fig. 9). The utilization of a thin custom-made rigid reamer is of value because it can further "guide" the entry point in the most appropriate position, just levering the reamer toward the direction of the floor, so that anteriorly angling the reamer ensures appropriate anterior trajectory. Once the position of the entry reamer is checked radiographically, the rigid reamer and guide pin are removed, maintaining *in situ* the protective sleeve. A ball-tipped guide wire is then introduced into the medullary canal, advanced across the fracture site, and impacted into the subchondral bone of the distal tibia. Sequential reamers are then placed through the entry sleeve, to protect intra-articular structures (Fig. 10). The sleeve can accommodate up to a 12 mm reamer. Because of the semi extended position of the patient, our experience suggests to utilize a short (at least 80 cm) ball-tipped guide wire. A conventional guide wire is in fact 100 mm long and could protrude outside the surgical field towards the head of the patient when implemented in a semi-extended procedure, with risks of contamination. As a result, the measuring device to read the length of the nail is thus to accommodate such a modified ball tip guide wire. In contrast, it is also advisable to have in the operating room flexible reamer extensions, in case the combination of the suprapatellar entry point and the protection sleeve results in a length discrepancy with the conventional reamers. The senior author also suggests the use of a conical measuring device that could be easily introduced in the soft tissue or the sleeve. The tibial nail is then placed down the canal using a dedicated stainless steel handle, which can be hammered when necessary, and an extended proximal jig is used to place the crossed locking screws. This jig is longer than the similar device used in the tendon splitting or parapatellar approaches: it extends from the incision to the proximal tibia. It allows screw insertions in the coronal plane, in two oblique planes at 40° and out of nail to stabilize reduced articular fragment in a very proximal fracture. The distal locking screws are placed free hand under biplanar C-arm guidance choosing among different possible locking levels in both the coronal and sagittal planes. Final end cup application of different size permits to compensate eventual over sinking of the nail. Copious irrigation is suggested at the insertion of the nail to minimize the potential presence of osseous debris in the joint or the quadriceps muscle. Suture of the incision of the quadriceps tendon is easily accomplished with a couple of

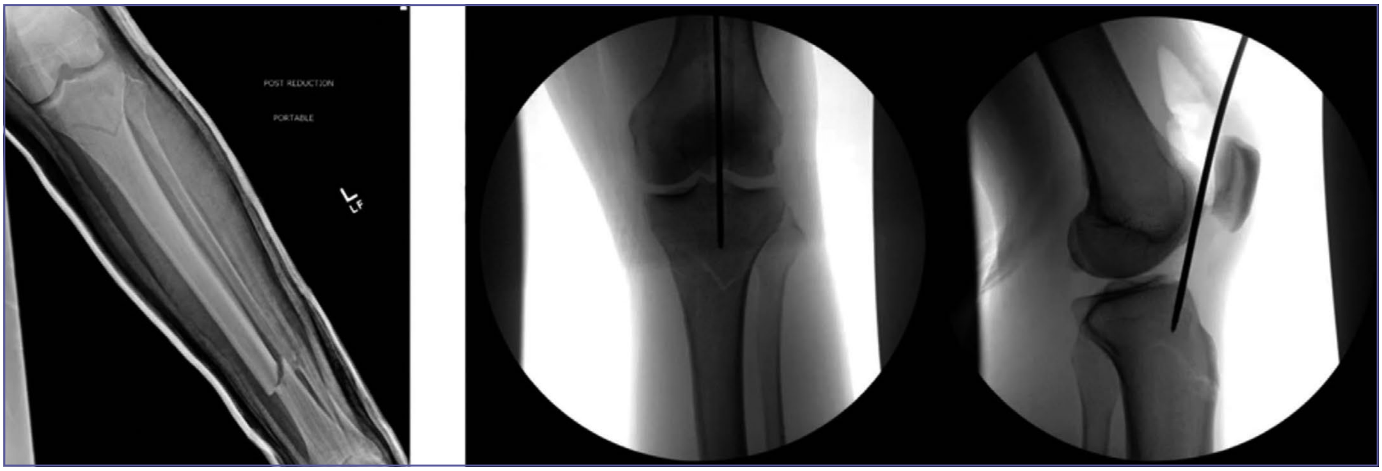

Figure 7. Suprapatellar tip: if difficulty with starting point , insert guide pin first and then cannula and trochar.

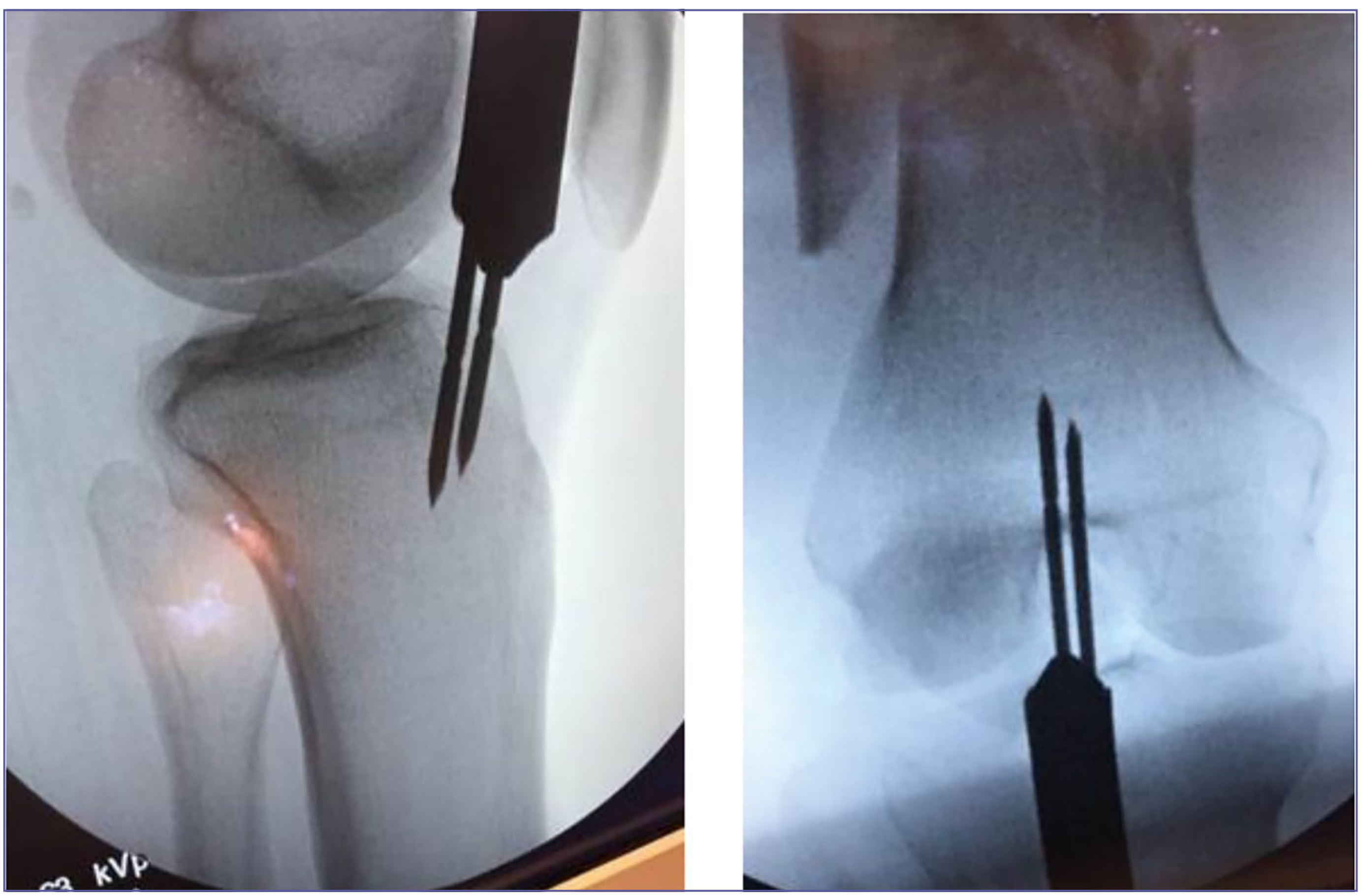

Figure 8. A multiholed guide pin sleeve ("honeycomb") is available allowing for fine adjustments of the starting point.

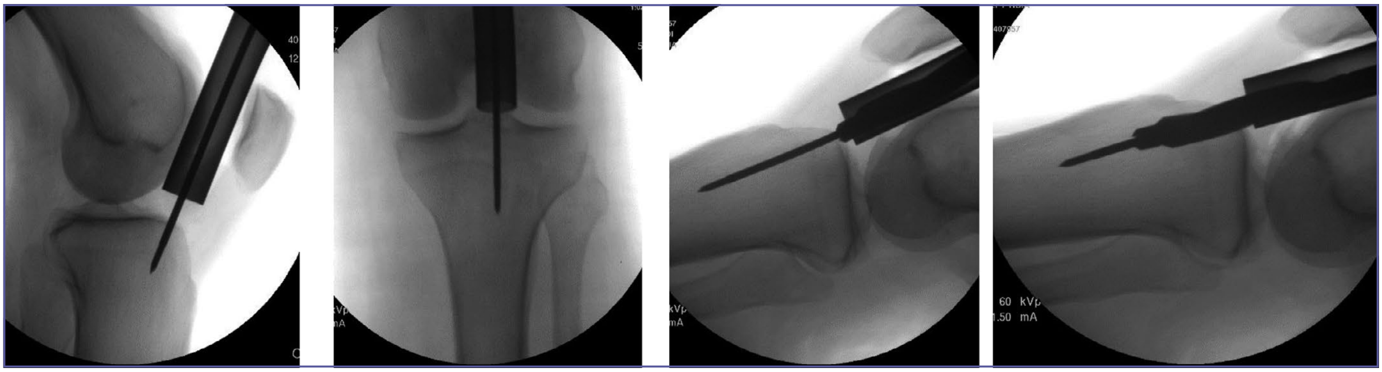

Figure 9. Trochar has been removed and substituted by the rigid reamer.

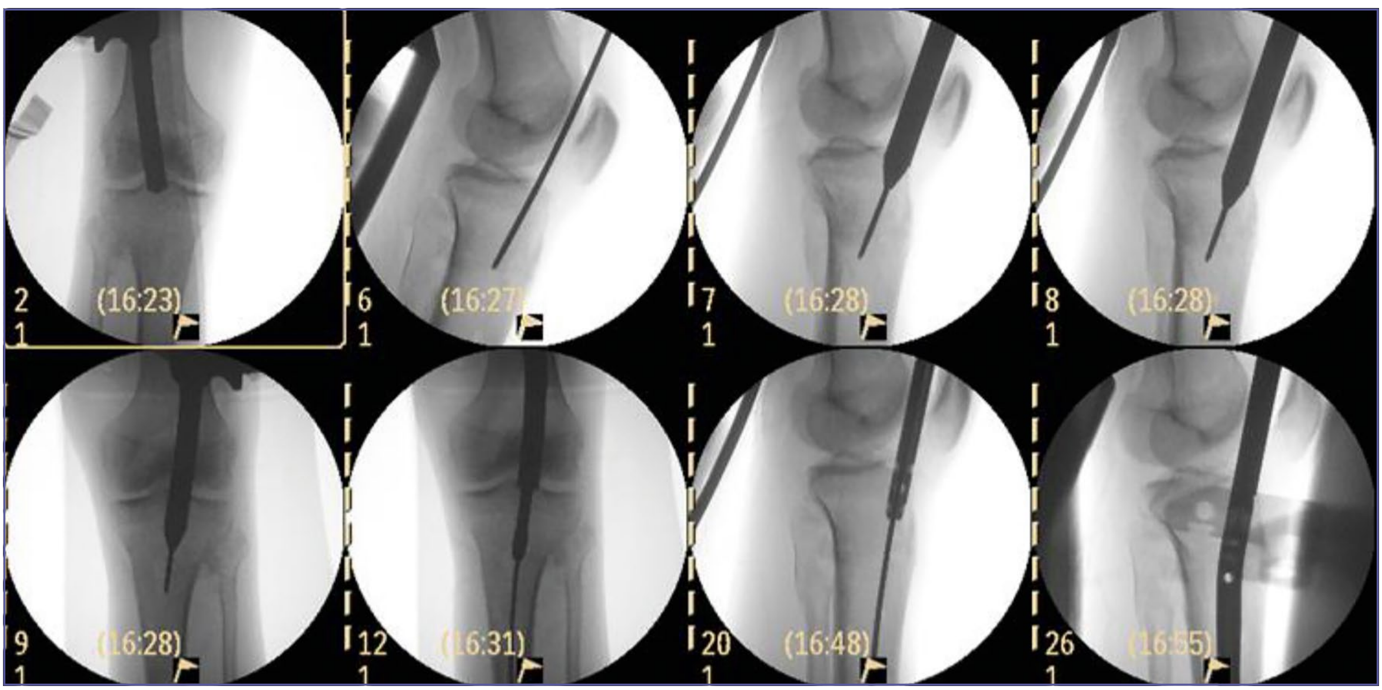

Figure 10. Placement of guide wire, 12.5 mm entry rigid drill through a drill sleeve. Sequential reaming.

deep sutures. Iodoform gauze is implemented in the dressing of the cutaneous wounds and the patient leaves the operating room with a posterior splint with the ankle at 90° for the first few days post-operative.

Discussion

Intramedullary nails for stabilization of tibia fractures have evolved since the days of Küntscher**.** Advances have been made in metallurgy and nail design, which have expanded the indications for intramedullary osteosynthesis of tibial fractures. The EstreMO nail (Citieffe® s.r.l. Italy) is the latest generation nail, expressively designed for the suprapatellar entry. The conventional classic parapatellar and transtendon approaches are associated with post-operative knee pain [34-37]. The etiology of this pain is likely multifactorial including stretching the tendon intraoperatively, damage and scarring to the soft tissues, and infrapatellar nerve injury. This pain has significant impact on patient outcomes, particularly in young manual laborers who ironically are most commonly affected by tibial shaft fractures. The suprapatellar incision theoretically avoids these potential causes of pain, likely improving patient outcomes and increasing patient satisfaction. It also allows the patient to diminish the periods of limited activity because of the healing of a split tendon. This can be particularly important for athletes [31,32]. With our experience,

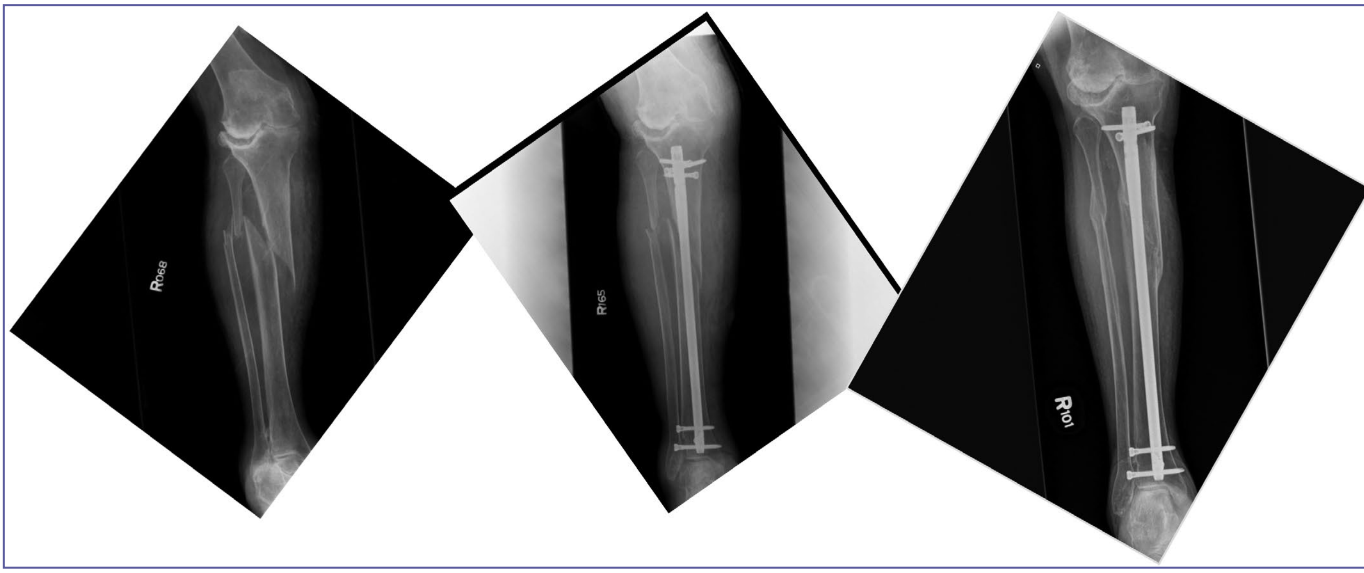

Figure 11. 83-years-old patient with severe knee arthritic changes at 4 months post-operative. Full weight bearing at 3 weeks.

we also recommend this approach in patients who are prone to frequent kneeling down, because of work activity or religious traditions. The presence of osteoarthritic changes in senior patients are not a contraindication and actually facilitate unrestrained precocious ambulation (Fig. 11). The same can be said of patients undergoing a varus/valgus osteotomy for tibia mal union or non-union as well as intramedullary fixation of previous bone lengthening or bone transporting procedures according to the Ilizarov method. In proximal oblique metaphyseal fractures, with posterior cortical extension, the suprapatellar technique reduces the risk of posterior cortex perforation by placing the starting point in line with the medullary canal (Fig. 12). This technique helps to reduce varus and valgus deformities by using the femoral trochlear groove as a guide for its starting point, thus maintaining the mechanical axis of the lower extremity. In addition, the suprapatellar approach gives the orthopedic surgeon convenient access to the "safe zone" on the tibial plateau [30] and helps obtain more consistent starting portal placement in a closed manner. A potential criticism of this approach is the intra-articular involvement and the potential for patellar or trochlear chondral injury. Although this approach does transverse the patellofemoral joint, the entry sleeve is in place during reaming, protecting the chondral surfaces from iatrogenic damages. According to several recent cadaveric studies [38-45], this route might be used safely with the aid of a protection sleeve. Gelbke et al. [44] also studied the patellofemoral contact pressure differences between suprapatellar and intrapatellar nailing techniques and concluded that although the former is higher, it remains well below the values of potential damages to the articular cartilage.

Comments

In conclusion, we consider the percutaneous suprapatellar approach in a semi-extended position an excellent option for intramedullary nailing of tibia fractures at all levels[13,18], which has reached increased popularity (Fig. 13). Sagittal plane alignment with the tibia maintained in a semi-extended position, parallel to the floor, results in simplified operating

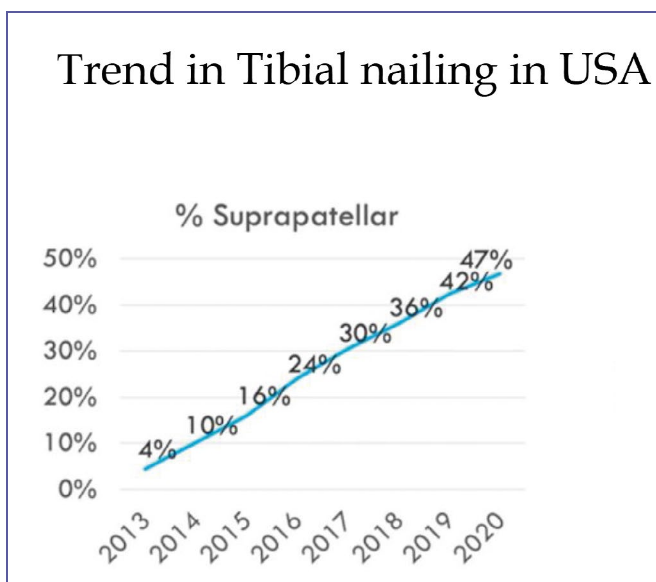

Figure 13. The trend in Intramedullary tibial nailing in the US.

Figure 12. Intramedullary ExtreMO tibia nail in tibia fracture(A and B).

room preparation, draping is easier, and radiographic imaging is simplified. There is no need to setup fracture tables and it is ideal in a polytrauma situation. Reduction of the fracture can be obtained with the limb in line, with minimal longitudinal manual traction and /or percutaneous clamps; there is no need to hyperflex the knee to introduce the nail, with potential consequences of mal reduction with anterior opening of the fracture. Moreover, there is neither direct damage to the patellar tendon nor the infrapatellar nerve, with less chance of anterior knee pain. Combined with an extraordinary simplified stabilization and fixation of proximal tibia fractures, it can be implemented in all kinds of diaphyseal or metaphyseal fractures because of the direct internal alignment that is obtained. The approach has to be combined with an implant set that includes a specifically designed nail, instrumentation, targeting and measuring devices, as well as protecting sleeve and trochar. The EstreMO nail system implements all these features in a design that is unique: all other intramedullary nails were commonly utilized well before the advent of the suprapatellar entry point in semi-extension [46,47].

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Conflict of interest statement
The author declares no conflict of interest.

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Ethical consideration
This study was approved by the Institutional Ethics Committee (LSU-Shreveport) (Study 00000624).
The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.
Written informed consent was obtained from each participant/patient for study participation and data publication.

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