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ORIGINAL STUDY

Impact of posterior tibial nail malpositioning on iatrogenic injuries by distal medio-lateral interlocking screws
A cadaveric study on plastinated specimens

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In intramedullary tibial nailing, multi-planar locking makes stabilization of proximal and distal metaphyseal fractures possible. A known complication in intramedullary nailing of the tibia is iatrogenic injury to neuro-vascular structures caused by the insertion of locking screws. As shown in previous studies, the distal positioning of the nail is important, as it determines the course of the locking bolts. The goal of the present study was to display the consequences of posterior nail malpositioning with respect to the safety of the distal medio-lateral locking screws and the available options. Human cadaveric legs were plastinated according to the sequential plastination technique after intramedullary nailing of the tibia and were then cut transversely. The tibial nails were placed centrally or posteriorly. Macroscopic analysis showed a distinct drawback of posterior nail positioning, with diminished options for the placement of the locking screws and thereby a risk of damaging the anterior and posterior neuro-vascular bundles by distal medio-lateral locking screws.

Keywords : tibial nailing ; multi-planar locking ; iatrogenic injury ; locking bolt ; posterior malpositioning.

INTRODUCTION

Over the years, since tibial intramedullary nailing has become widely accepted in the treatment of tibial shaft fractures, its indications have been extended to proximal and distal metaphyseal fractures of the tibia (*2,16,22*). Standard tibial nails with locking screws oriented in the frontal plane have failed the biomechanical requirements in proximal or distal tibial fractures and have lead to non-unions and to secondary axis deviations (*8,19*). Intramedullary nails featuring a multiplanar insertion of proximal and distal locking screws were therefore developed and have allowed for a stable fixation in proximal and distal tibial fractures (*2,4,10,16,18*). Neurologic complications in tibial nailing have

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been reported in between 0.7% and 30% of the cases. In most of these cases, this occurs as a result of traction damage during the reposition maneuvers and by the impingement of neural structures ; it occurs less often through direct injury done by the drills or the implants (*14,15*). However, in the course of fracture treatment with multiplanar locking screws, reports of specific iatrogenic neuro-vascular injuries have been presented (*3,9,13,23*). Because of specific anatomic relations, the placement of antero-posterior and oblique locking screws carries a risk of neurovascular damage (*3,11,12*). Until now, it has not been demonstrated whether or not the positioning of the intramedullary nail in the sagittal plane influences the locking options at the distal tibia and its safety.

The goal of the present study was to display the impact of a posterior malpositioning in tibial nailing on the distal medio-lateral locking-options, with respect of a so called "safe zone".

MATERIALS AND METHODS

In the present study, human cadaveric lower legs were investigated, concerning the anatomic relations to distal locking bolts in tibial nailing. Therefore 3 lower legs were harvested at the Anatomic Institute of the University of Cologne. The 3 lower legs came from 2 donors, 1 male and 1 female. The average age of the donors at the time of death was 92.5, ranging from 91 to 94 years. The freshly frozen specimens were thawed and unreamed titanium nails (ETN, Synthes, Canada) were implanted by experienced trauma surgeons. The nails were locked multidirectionally, proximally and distally, at all available jig slots. Distally, 4 bolts were inserted. Following that, the specimens were plastinated according to the elaborate sequential plastination technique (*20*). The popliteal artery was identified, and through a cannula, the specimens were flushed with saline. Then, via gravity infusion, 2% formalin was instilled. After such a provisional fixation, the arterial vascular system of the lower legs was filled with epoxy resin mixed with red dye and lead oxide which worked as a contrast agent. Because of its molecular size of 60 µm, the dye cannot penetrate the vessel wall and selectively fills the arterial system. After the epoxy resin had hardened, the specimens were cut with a diamond-wire saw (Well, Mannheim, Germany) according to the anatomic planes in plates of 3-4 mm thickness. Then, the specimens were dehydrated at -25° C in acetone for a period of 2 months, before being defatted for a further 3 months and impregnated under vacuum conditions for 10 hours. The hardened plates were then ground and polished, to facilitate dying with methylene-blue and fuchsine, which enhances the contrasts between bone and soft tissue. After drying, the specimens were ready for analysis.

The analysis was conducted macroscopically with magnifier lenses and digitally via photo analysis software. The impact of tibial nail malpositioning on the options for placement of the locking screws in a so called "safe zone" was analyzed. The safe zone was defined as a quadrangular area, with the broader basis headed to the medial side, and the narrower tip headed to the lateral side of the lower leg. The basis reached from the flexor tendons posteriorly, to the extensor tendons at the anterior border. The tip was localized between the distal tibio-fibular joint posteriorly, and the neuro-vascular bundle anteriorly (Fig. 1).

RESULTS

The base of the safe-zone at the medial side of the leg was found to be 3.12 cm on average, narrowing down to its tip on the lateral side with 0.73 cm. No locking bolt placed into that zone, would endanger tendinous or neuro-vascular structures, nor the tibio-fibular joint.

A centrally placed nail offers various options for the placement of locking bolts in the "safe zone" at the distal tibia, displayed by a wide angular range of insertion (Fig. 1). In a slightly posterior nail malposition, as illustrated in Fig. 2, the angular range for the bolt insertion is already narrowed. This stands in contrast to a far posterior position of the intramedullary nail, where almost no placement of the locking bolt into the "safe zone" is possible. Even internal rotation can hardly facilitate adequate positioning, avoiding the distal tibio-fibular joint or the tendon of the tibialis posterior muscle.

DISCUSSION

The indications for tibial nailing have been extended over the past years (*2,16,22*). Therefore, nail design had to be changed, and multiplanar locking was introduced (*18*). Iatrogenic injuries to the nerves in the leg have been reported in relation

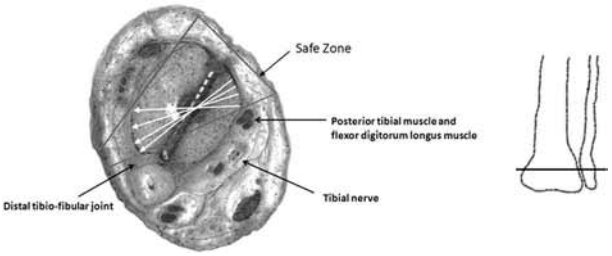

Fig. 1. — Impact of central nail positioning on the locking options in the "safe zone" at the distal tibia. White arrows represent possibilities for safe bolt placement. Several different possibilities of nail positioning, dependent on nail rotation, are available.

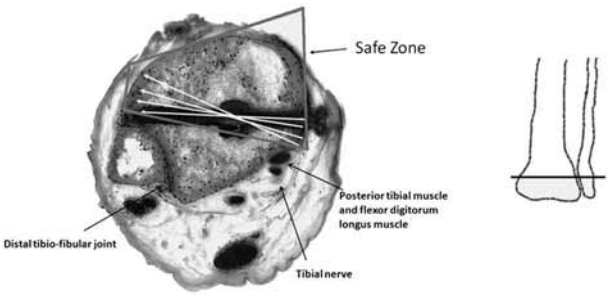

Fig. 2. — Impact of slight posterior nail malpositioning on the locking options in the "safe zone" at the distal tibia. White arrows represent possibilities for bolt placement. The possibilities for positioning of interlocking screws are reduced.

with tibial nailing (*1,5,27*). This has been commonly explained by neurapraxia due to traction or compression of the nerve during repositioning maneuvers (*24,27*). Several studies depicted the anatomic relations of the relevant structures to locking screws and other implants used in fracture fixation (*7,11,25*). For example, Drosos *et al* reported a case of direct damage to the peroneal nerve by a medio-lateral locking bolt and surmised "a new emerging complication" (*6*). Moreover, due to swelling from the injury and bleeding provoked by reaming in combination with the aforementioned traction, acute compartment syndrome may lead to neurologic damage (*26*). Yet authors recently reported specific lesions of neuro-vascular structures after using multiplanar locking bolts in proximal and distal tibial fractures (*9,11-13,23*). As shown in the present specimens, with malrotation and malpositioning of an intramedullary tibial nail, the placement of locking bolts can be complicated, or even be made

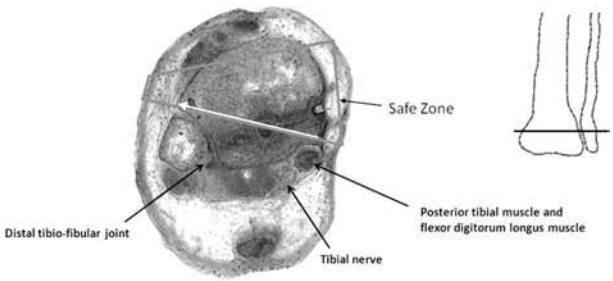

Fig. 3. — Impact of posterior nail malpositioning on the locking options in the "safe zone" at the distal tibia. White arrow represents the sole possibility for screw placement. Placement of the locking screw in the safe zone is almost impossible by far posterior nail positioning, as shown.

undesirable. In clinical practice, when complex fractures are treated with intramedullary nailing, an ante-curvated fixation of the distal part of the tibia is commonly accepted. This leads to a posterior positioning of the nail in the distal fracture fragment. Concerning medio-lateral screws, an eccentric posterior malposition of the nail diminishes the possibilities of placing a locking screw into the "safe zone", as shown by our specimens. In medio-lateral locking, the "safe zone" covers an almost triangular shape, reaching from the medial to the lateral cortex of the tibia, between the tibio-fibular joint and the extensor tendons (Fig. 1). The posterior, eccentric position forces the alignment of a medio-lateral locking bolt into conflict with either the tibio-fibular joint or the flexor tendons. According to the illustrations in the present study, we presume difficulties in placing a medio-lateral bolt into such a mal-positioned nail, and if positioned, a higher risk of iatrogenic injuries may be encountered. Thus, a posterior mal-positioning of intramedullary nails in the shaft of the tibia should be avoided. Therefore, a technique has been developed by Krettek *et al* using a blocking-screw. Blocking screws prevent posterior migration of intramedullary nails in the tibia, by forcing the nail to travel more anteriorly through the intramedullary canal (*16,17,21*). The blocking-screws can be inserted proximally, as well as distally, and can thereby effectively help to prevent posterior mal-positioning.

The specimens of the plastinated lower legs convincingly illustrate the endangerment of relevant

structures at the level of the distal tibia. The necessity for central nail positioning is reaffirmed. Caution and intensive training, along with subtle fluoroscopy, is necessary to avoid serious complications.

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