Tibia-Based Referencing for Standard Proximal Tibial Radiographs During Intramedullary Nailing

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Abstract

Limited information exists to define standard tibial radiographs. The purpose of this study was to define new landmarks on the proximal tibia for standard anteroposterior and lateral radiographs.

In 10 cadaveric knees, fibular head bisection was considered the anteroposterior image, and femoral condyle overlap the lateral image. In another 10 knees, a "twin peaks" anteroposterior view, showing the sharpest profile of the tibial spines, was used. The "flat plateau" lateral image was obtained by aligning the femoral condyles then applying a varus adjustment with overlap of the tibial plateaus. Medial peritendinous approaches were performed, and an entry reamer used to open the medullary canal.

A priori analysis showed good to excellent intra-/inter-observer reliability with the new technique (intra-class correlation coefficient ICC 0.61-0.90). The "twin peaks" anteroposterior radiograph was externally rotated 2.7°±2.1° compared to the standard radiograph with fibular head bisection. Portal position and incidence of damage to intra-articular structures did not significantly differ between groups (P>.05).

The "twin peaks" anteroposterior view and "flat plateau" lateral view can safely be used for nail entry portal creation in the anatomic safe zone. Tibia-based radiographic referencing is useful for intramedullary nailing cases in which knee or proximal tibiofibular joint anatomy is altered.

Intramedullary nailing (IMN) has become the treatment of choice for unstable tibia fractures with numerous studies showing improved outcomes compared to conservative treatment. Tornetta and colleagues[1] originally described a "safe zone" for nail placement based on anatomic landmarks in order to minimize injury to the menisci and articular cartilage. Later, he identified the radiographic correlates to this anatomic safe zone as "just medial to lateral tibial spine on the anteroposterior (AP) radiograph and immediately adjacent and anterior to the articular surface on the lateral radiograph."[2] However, limited information exists defining standard AP and lateral radiographs.

Tibial radiographs have been shown to appear AP through a 30° rotational arc, thus leading to an improper translation of the correct intramedullary nail starting point by up to 15 mm.[3] Since the safe zone can be as narrow as 12.6 mm,[1] understanding and obtaining a true AP radiograph of the proximal tibia becomes essential. Walker and colleagues[4] recently showed that the nail entry point significantly varies with tibial rotation. Furthermore, they found that an AP radiograph with the fibular head bisected by the lateral tibial cortex correlated with an entry point that was ideal or up to 5 mm lateral. Although useful in most situations, this reference point can be unreliable, as marked variability between individuals has been shown to exist in the proximal tibiofibular joint.[5,6] In addition, an associated proximal fibular fracture or tibiofibular joint dislocation can exist, thereby further altering the reliability of this landmark.

Similarly, the lateral radiograph is commonly referenced from overlap of the femoral condyles. However, normal valgus/varus variation and pathologic processes such as arthritis can alter their relationship to the tibia. This could lead to the intramedullary nail starting point being placed too proximally or distally on the proximal tibia, possibly resulting in increased intermeniscal ligament or anterior tibial cortical damage, respectively.

Dependable radiographic landmarks on the tibia itself are necessary for determining AP and lateral radiographic views for situations when the current standard radiographs are not reliable due to patient anatomic variation or pathology in the knee or tibiofibular joints. The purpose of this study was to define new radiographic imaging landmarks on the proximal tibia for standard AP and lateral radiographs, and to compare intra-articular damage from nail entry portal creation with previous radiographic techniques.

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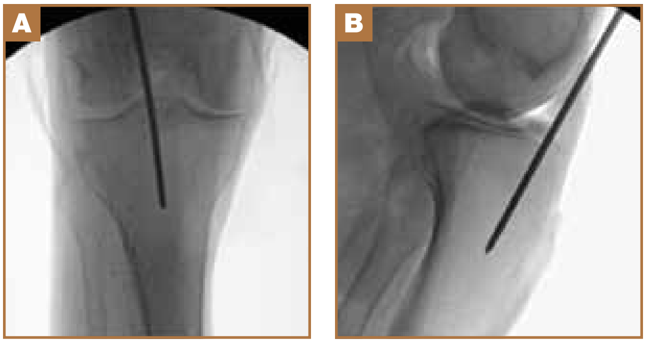

Figure 1. AP radiograph (A) and lateral radiograph (B) using standard techniques, with the fibular head bisected on the AP view, and the femoral condyles aligned on the lateral view.

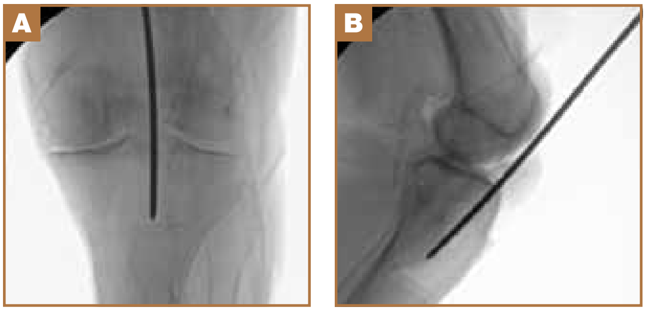

Figure 2. AP radiograph (A) and lateral radiograph (B) using new modified radiographic technique, with the "twin peaks" AP view, and the "flat plateau" lateral view.

Materials and Methods

Twenty cadaveric knees (10 matched pairs) were used for this study. A 3 cm longitudinal, medial parapatellar incision was made in each knee with special care taken to not injure any underlying structures. Biplanar fluoroscopic imaging was then used to determine the correct starting point for guide pin placement. This was defined as just medial to the lateral tibial spine on the AP radiograph, and immediately anterior to the articular surface on the lateral radiograph.[2]

In Group 1 (10 knees), one lower extremity of each cadaver (5 left and 5 right), a fluoroscopic technique[4] was used with bisection of fibular head considered the AP image, and femoral condyle overlap with rotational or sagittal alignment the lateral image (**Figure 1A**). In Group 2 (10 knees), the "twin peaks" AP view of the contralateral lower extremity of each cadaver (5 right and 5 left) showing the sharpest profile of the tibial spines perpendicular to the tibial plateau was used as the AP image. The "flat plateau" lateral image was obtained by aligning the femoral condyles rotationally and sagittally, and then applying a varus adjustment of the image to be perpendicular with overlap of the medial and lateral tibial plateaus.

Using a soft tissue protective sleeve, a 3.2-mm-threaded guide wire was then inserted approximately 3 cm into the proximal tibia. Next, a 12.5 mm entry reamer (Smith and Nephew, Memphis, Tennessee) was placed over the guide wire through the protective sleeve. After radiographic confirmation that the reamer was contacting bone and in its desired trajectory, it was advanced under power approximately 4 cm into the medullary canal before being removed.

All soft-tissues were then carefully removed from each knee preserving both medial and lateral menisci, meniscotibial ligaments, and articular surfaces as well as the anterior cruciate ligament (ACL) insertion and anterior intermeniscal ligament. Any damage to each of these structures was recorded. If the intermeniscal ligament had damage noted but remained in continuity with at least 1 mm of traversing fibers intact, it was recorded as partial disruption.

Distances from the menisci, articular surfaces, and ACL footprint to the nearest point of the entry portal were measured using a digital caliber. Next, all soft tissues were completely removed before calibrated digital images were taken of the entry portal. To confirm that no additional bony destruction had occurred during soft tissue removal, the entry reamer was replaced by hand into the portal to verify that a relative line-to-line fit remained after photographs were taken. From the calibrated digital images, the size of osseous defect created in the proximal tibia was calculated using Adobe Photoshop CS5 (San Jose, California). This process involved comparing the number of pixels in the entry portal to a standardized object of known size.

Reliability analysis involved determining the intra- and inter-observer reliability for 3 examiners in determining the modified AP and lateral radiographic images. This reliability was assessed using the intra-class correlation coefficient (ICC) using 2-way random effects ANOVA and the consistency definition. The following classification scheme, proposed by Fleiss,[7] was used for ICC interpretation: <0.40, poor; 0.40 to 0.59, fair; 0.60 to 0.74, good; >0.74, excellent. Statistical analysis comparing the above anatomic measurements from the standard and modified radiographic techniques included paired t-tests and Fisher's exact tests using SPSS 20.0 software (IBM, Armonk, New York). Statistical significance was established at a level of P<.05.

Results

Reliability analysis showed borderline excellent intra-observer (ICC, 0.73; 95% confidence interval [CI] 0.40-0.93) and good inter-observer reliability (ICC, 0.61; 95% CI, 0.22-0.88) on the modified "twin peaks" AP view. Excellent intra-observer (ICC, 0.90; 95% CI, 0.72-0.97) and inter-observer reliability (ICC, 0.78; 95% CI, 0.48-0.94) was found on the "flat plateau" lateral view.

On average, the modified "twin peaks" AP radiograph was externally rotated 2.7±2.1° (range, 1.2° internal to 8.4° external) using the fibular head bisection line, compared with standard radiograph. This corresponded to an average of 1.8±2.1 mm (range, -5.6 mm to 0.8 mm) more overlap of the fibula. The modified "flat plateau" lateral radiograph involved directing the fluoroscopic beam 1.6±2.9° (range, -4.0 ° to 5.0°) caudal varus, compared with perfectly aligned femoral condyles.

The average portal position relative to adjacent intra-articular

Table I. Average Distance Between Portal, Surrounding Anatomic Structures, and Entry Portal Size

	Radiographic Technique	
Anatomic Measurement (average mm ± SD)	Standard (Group 1)	Modified (Group 2)
Portal to medial meniscus	2.8±3.2	1.9±2.3
Portal to lateral meniscus	7.0±4.2	8.5±4.5
Portal to medial articular surface	6.4±3.8	4.6±4.3
Portal to lateral articular surface	7.6±4.1	8.8±5.0
Portal to ACL footprint	4.1±3.1	3.8±3.0
Mid-portal to mid-tibial plateau*	4.4±2.5	4.1±2.9
Articular surface to distal portal	12.9±7.0	9.9±7.0
Distal portal to start of tubercle	11.4±7.3	12.2±9.2
Portal entry coronal width	14.3±1.0	14.1±1.3
Portal entry sagittal length	18.8±2.7	17.8±4.3
Portal surface area (mm^2)	205.1±38.4	189.0±32.0

No significant differences (P<.5) were seen between radiographic techniques and above measurements
* Positive values represent toward the lateral direction and negative values medial direction

structures did not significantly differ between radiographic techniques, with the portal from the modified technique (Group 2) slightly more medial and proximal than the standard technique (Group 1) (**Table I**). On average, the portals came in closest proximity to the medial meniscus at a distance of 2.8±3.2 mm for the Group 1, and 1.9±2.3 mm for Group 2. Furthermore, the average portal dimensions and surface area of bone removed with creation of the portal did not significantly differ between techniques with Group 1 measuring 205.1±38.4 mm^2 of bone removed, versus 189.0±32.0 mm^2 removed in Group 2.

Injury of the intra-articular structures is summarized in **Table II**. Only the lateral meniscotibial ligament and anterior intermeniscal (IM) ligament were damaged in Group 1; however, no knee went without some damage to an intra-articular structure. In Group 2, both medial and lateral meniscotibial ligaments and IM ligament were damaged, and 2 of the 10 knees had no damage to intra-articular structures.

The IM ligament was present in all 20 knees. With the standard fluoroscopic technique (Group 1), it was damaged in 80% of knees, with partial disruption in 50% and complete disruption in 30%. Likewise, using the modified fluoroscopic technique (Group 2), it was damaged in 70% of knees, with partial disruption in 40% and complete disruption in 30%.

Discussion

Chronic anterior knee pain remains problematic following tibia IMN. Several possible etiological factors have been discussed, including damage to intra-articular structures and anterior tibial cortical bone loss.[8-10] With such a wide range of reported incidence of knee pain (10-86%) and the exact etiology likely multifactorial,[9,11-16] it becomes especially important that entry portal placement be as close as possible to the anatomic "safe zone" originally described by Tornetta and colleagues[1] in 1999. He later described the radiographic correlate of this safe zone as just medial to the lateral tibial spine on the AP radiograph.[2] However, it was not defined what should be considered as the standard AP radiograph. This is important, as clearly the entry point into the tibia is altered significantly with tibial rotation on fluoroscopic imaging.

Walker and colleagues[4] reported that an AP radiograph with the fibular head bisected by the proximal lateral tibial cortex correlated with an entry point that was ideal or up to 5 mm lateral. Given that this reference may be unreliable in certain situations based on trauma or variable anatomy, radiographic landmarks based on tibial landmarks are necessary. We found that our tibial based referencing technique with the "twin peaks" AP view and the "flat plateau" lateral view was as accurate as the standard techniques based on utilizing the proximal tibiofibular joint for the AP image and the knee joint for the lateral image. Both techniques were accurate in placing the entry portal in the safe zone without any significant differences between them.

Table II. Incidence of Damage to Intra-Articular Knee Structures

	Percentage of Knees Involved	
Structure Damage	Standard Fluoro Technique (Group 1)	Modified Fluoro Technique (Group 2)
Medial meniscus	0	0
Lateral meniscus	0	0
Medial meniscotibial ligament	0	20
Lateral meniscotibial ligament	30	20
Anterior intermeniscal ligament	80	70
- Partial disruption	50	40
- Complete disruption	30	30
ACL footprint	0	0
All structure intact	0	20

Using a medial peritendinous approach as in this study, Tornetta and colleagues[1] reported a 20% incidence of intra-articular damage. However, the incidence of damage to the anterior IM ligament was not reported. In this prior study's figure illustrating the safe zone for nail placement, the IM ligament is depicted crossing through the safe zone. As our average distances between the portal and surrounding anatomic structures were very similar to this early paper describing the ideal nail placement, our results suggest that the IM ligament is damaged during the majority of tibial nail preparations placed in the safe zone, no matter the radiographic technique used. The significance of the IM ligament remains debated. In biomechanical studies, inadvertent sectioning of the IM ligament has been shown to not adversely affect either menisci or tibiofemoral contact stresses.[17] Conversely, histological sectioning of IM ligaments have found the presence of free nerve endings and mechanoreceptors, suggesting a proprioceptive role for the IM ligament.[18]

Certain aspects of this study differ from the recent work by Walker and colleauges[4] that warrant further discussion. First, they reported that tibial external rotation led to a misleading medial entry point. Our results do indicate that on average, tibial external rotation does lead to a minor medialization of the entry point. However, this change of 1.6° compared to fibular head bisection did not lead to a significant change in portal placement or incidence of intra-articular structural damage. Second, they briefly state that the shape of the spines were not helpful in distinguishing between films, but do not provide any objective data supporting this statement. Both the intra-observer and inter-observer reliability were found to be good to excellent in our study, while the average distances from intra-articular structures were similar to prior studies looking at the safe zone. Both of these findings suggest that this modified technique is reproducible and accurate for entry portal placement.

The current study does have limitations. There were a small number of cadavers utilized. Although no significant differences were seen between radiographic techniques, it is unlikely that any statistically significant difference that might arise with a higher-powered study would be of clinical significance. Another potential limitation is that cadavers were embalmed versus fresh frozen, which may limit soft-tissue pliability and thus reamer trajectory. Therefore, our results may represent the lower extent of intra-articular and cortical damage.

Radiographic referencing based on tibial anatomy was shown to have excellent intra-observer and inter-observer reliability. The "twin peaks" AP view and the "flat plateau" lateral view can safely be used for tibial nail entry portal creation in the anatomic safe zone, with no differences found for damage to intra-articular structures when using previous radiographic techniques. Tibia-based radiographic referencing can be useful for intramedullary nailing cases in which local knee or proximal tibiofibular joint anatomy is significantly altered.

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This paper will be judged for the Resident Writer's Award.