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Can the use of femoral notch view alone decrease measurement error of distal interlocking screws after retrograde femoral nailing

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ABSTRACT

Objectives: Determine if using different fluoroscopic views of the knee (Notch or Tangential) improves accuracy of screw lengths assessment compared to the standard posteroanterior (PA).
Participants and Methods: Orthopaedic surgeons at three ACGME-accredited residency programs were asked via survey to assess screw lengths on PA, femoral notch, and tangential radiographic views.
Results: Responders correctly identified screw length using PA, femoral notch, and medial tangential views at rates of 46.75%, 52.27%, and 44.37% respectively. Respondents detected overall screw length discrepancies most accurately using the femoral notch view (Odds Ratio 1.26; 95% confidence interval: 1.07–1.47; $P < 0.005$). There was no statistical difference between the residents and faculty cohort in ability to detect screw length discrepancy.
Conclusion: Differentiating distal interlocking screw lengths on traditional imaging (AP/Notch/Tangential) is poor. The femoral notch view significantly improves accuracy in radiographic determination of screw length. The femoral notch view should be used in conjunction with the traditional PA view to maximize sensitivity and specificity for detecting prominent screws.

Introduction

Knee pain following intramedullary nailing of the femur is not uncommon with its incidence as high as 86% and 37% with retrograde and antegrade approach respectively [1–8]. The most common causes of knee pain from retrograde intramedullary nailing are related to soft tissue irritation often resulting from the protrusion of distal interlocking screws [3,6,7]. This often leads to additional surgical procedures to remove symptomatic implants leading to a significant healthcare and economic burden [9].

The posteroanterior (PA) view of the knee is often used to confirm final distal interlocking screw position. This technique is fraught with difficulties due to the trapezoidal shape of the distal femur, with the anterior surface being narrower than the posterior surface. As a result, screws that appear to be of appropriate length are in fact prominent. Imaging techniques other than PA imaging may help improve the accuracy of measurement however, little work has been conducted to assess alternative imaging. [10]

Improvement in the accuracy of screw placement has potential to decrease rates of symptomatic implant removal after retrograde femoral nailing. The purpose of this study was to determine if different fluoroscopic views of the knee (Notch or Tangential) could improve the accuracy of radiographic screw length assessment.

Materials and methods

Cadaver preparation

Four cadaveric lower limb specimens (2 left, 2 right) were used to simulate retrograde femoral nailing surgical procedures. Cadaveric specimens were free from any history of trauma or deformity of the bony structure and soft tissues in the lower extremity. Using manufacturer recommended techniques, 4 retrograde femoral nails (T2 Retrograde Femoral Nail, Stryker, Kalamazoo, MI, USA) were inserted. Only the most distal interlock was utilized to ensure that the distal interlocking screw was placed within 40-mm proximal to the joint line, which has been associated with increased need for removal. [11] Screws were placed either flush with the medial cortex, 2-mm short or 2-mm

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long, as confirmed with direct visualization via dissection and measurement utilizing a ruler.

Image preparation

Three fluoroscopic views of the knee were used in this study to assess screw length (PA, Notch, and Medial Tangential). For each specimen and each screw length (3 per sample), these three images were taken, repeated, and compiled for the different screw depths. The femoral notch view was obtained with 45° of knee flexion with a 10° cephalad tilt of the X-ray beam (Siemens, Germany). [12] The medial femoral tangential view was obtained by adjusting the direction of the fluoroscopic x-ray cathode (Siemens, Germany) 40° external rotation from the sagittal plane [10]. All images were made to simulate the appearance of an intraoperative fluoroscopic view of the knee as can be seen in Fig. 1.

Survey

During the second portion of the IRB approved study, an online anonymous survey (SurveyMonkey®, www.surveymonkey.com, Palo Alto, CA, USA) was generated and sent to participants. The survey responses were anonymous and participation was completely voluntary. To preserve the anonymity of individual responses, the surveys were not linked in any way that could identify the respondents.

The survey was comprised of two sections. In the first section, responders were asked to indicate education background information including post graduate year (PGY) for residents and number of years in practice and subspecialty training for faculty. The second section consisted of a total of the 36 radiographs previously taken (4 samples × 3 lengths × 3 views = 36), randomly presented to the respondent. Survey participants were asked to judge whether the screw was “too short”, “too long”, “correct length”. Participants were provided with the definitions for screw length, with “correct length” being flush with the medial cortex, without screw tip penetration past the medial cortex. “Too short” was described as approaching, but not flush with the medial cortex. “Too long” was defined as the screw tip passing the medial cortex. Only the data from the online survey were used for the analysis of this study.

Population

Three ACGME accredited residency programs were included in the survey. 141 total surveys were sent. Seventy-five percent (106 of 141) of participants responded. Resident responses made up 62% (66/106) and 38% (40/106) consisted of faculty members. A breakdown of faculty experience, subspecialty and resident PGY can be found in Table 1.

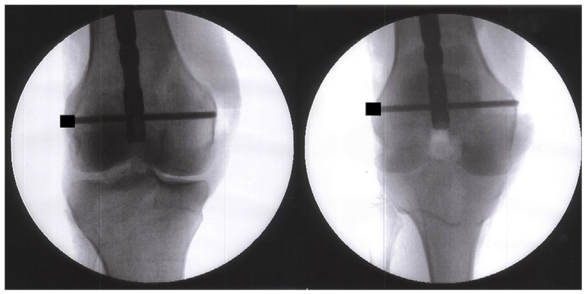

Fig. 1. PA and Femoral Notch (from Left to Right) of a 2-mm Prominent Screw. The screw head was blocked out on the radiographs so that respondents would not report the prominence of the screw head.

Table 1
Resident, Attending and Fellow Experience.

Attending Experience (n)	
Fellow:	7.5% (3)
< 5 Years:	18% (7)
5-10 Years:	25% (10)
10-15 Years:	10% (4)
>15 Years:	40% (16)
Attending Specialty (n)	
Trauma:	30% (12)
Pediatric:	22.5% (9)
Sports Medicine:	15% (6)
Foot and Ankle:	7.5% (3)
Oncology:	7.5% (3)
Spine:	5% (2)
Joints:	5% (2)
Hand:	5% (2)
Shoulder and Elbow:	2.5% (1)
Post Graduate Fellow:	7.5% (3)
Resident Experience (n)	
PGY 1:	18% (12)
PGY 2:	20% (13)
PGY 3:	18% (12)
PGY 4:	21% (14)
PGY 5:	23% (15)

Statistical analysis

Descriptive analysis was performed using chi-square tests (χ^2). In this survey, the overall correct response in distal interlocking screw placements by 3 fluoroscopic views of the knee (AP, Notch or Tangential) were tested for each of the following descriptive characteristics, stratified by the different modes: faculty vs. residents, faculty experience years, resident postgraduate level and faculty specialty by trainings. An odds ratio with 95% confidence interval (CI) estimated differences of 3 fluoroscopic views of the knee between Notch or Tangential and AP to detect screws that were placed 2-mm long or 2-mm short. A P value <.05 was considered statistically significant. All analyses were conducted using STATA 14 (College Station, TX).

Sensitivity and specificity were calculated for each view (PA/Notch/Tangential) for 2 mm prominent screws.

Results

Not all participants completed the survey. The resident cohort answered on average more questions than faculty, 33.91 ± 5.15 questions vs faculty 29.82 ± 11.81 questions ($P < 0.016$).

Respondents were able to detect overall screw length discrepancies most accurately using the femoral notch view compared to using the PA view (Odds Ratio [OR] 1.26; 95% confidence interval [CI]: 1.07–1.47; $P < 0.005$) (Table 2). When the images were stratified according to their corresponding screw length, our cohort of responders correctly identified the distal interlocking screws that were “too long” most frequently using the PA view (51.65%) versus 44.42% and 22.76% using the femoral notch view and medial tangential view, respectively (Table 2). When evaluating the distal interlocking screws that were the “correct length”, the responders answered correctly most frequently using the femoral notch view (59.73%) versus 46.17% and 49.15% femoral notch and medial tangential view (Table 2) When evaluating the distal interlocking screws that were “too short”, the responders answered correctly most frequently with the medial tangential view 76.21% versus 43.27% and 57.18% PA view and femoral notch view, respectively (Table 2).

The PA had 51.6% sensitivity and 80.2% specificity to detect a screw as being 2-mm prominent. The associated positive predictive value (PPV) and negative predictive value (NPV) were 56.8%

Table 2
Accuracy of detection, stratified by screw type.

View	*Total number of responses (N)*	*% Correct answers (Long)*	*OR*	*CI*	*P*
Overall Detection of Distal Interlocking Screw Length Discrepancy to PA View					
PA	1277	46.75			
Notch	1176	52.47			*0.005*
Tangential	1075	44.37			*0.248*
Long Screw Detection					
PA	395	51.65			
Notch	493	44.42	0.73	0.55-0.96	*0.025*
Tangential	492	22.76	0.25	0.18-0.34	*0.001*
Correct Length Detection					
PA	392	46.17			
Notch	293	59.73	1.76	1.29-2.40	*0.001*
Tangential	293	49.15	1.13	0.83-1.54	*0.433*
Short Screw Detection					
PA	490	43.27			
Notch	390	57.18	2.11	1.54-2.89	*0.001*
Tangential	290	76.21	6.81	4.60-10.08	*0.001*

and 76.6%. The femoral notch view had an associated sensitivity and specificity of 50.5% and 87.1% respectively for 2-mm prominent screws. The associated PPV and NPV for the femoral notch view were 67.2% and 77.7% respectively. The medial femoral tangential view had an associated sensitivity and specificity of 27.5% and 94.3% respectively for 2-mm prominent screws. The associated PPV and NPV for the tangential view was 71.1% and 72.1% respectively.

There was no statistical difference between the residents and faculty cohort in ability to detect screw length discrepancy (residents: 48 ± 0.09%, faculty: 49 ± 0.13%; P < 0.43) (Table 3). Both groups were best at distinguishing screw length discrepancies using the femoral notch view (OR 1.35; 95% CI 1.11–1.64, P < 0.003) compared to the PA view. No significance was detected in both groups using the medial tangential view (OR 0.92; 95% CI 0.75–1.12; P < 0.401) compared to the PA view. Trauma fellowship trained surgeons were slightly more accurate at identifying screw length discrepancies than non-trauma fellowship trained surgeons, although statistically insignificant (Trauma fellowship trained [n = 12]: 51% vs 48%; P < 0.59). Similarly, when trauma fellowship trained surgeons were compared with the resident cohort, no statistical significance was observed in the accuracy of detecting screw length discrepancies (trauma fellowship trained 51% vs 48%; P < 0.33).

Discussion

Despite knee pain from prominent hardware in retrograde nailing being common, little research has focused on ways to prevent this complication. This is surprising, considering that up to 12–37% of patients elect to undergo hardware removal [8,13]. One would hope that good surgical technique with proper measurement and radiographic confirmation would help prevent this complication. However, measurement utilizing depth gauges can be confounded by interposed soft tissue. Intraoperatively fluoroscopy, which commonly utilizes the PA view, is also limited in accuracy by the shape of the distal femur.

Table 3
Accuracy of detecting screw lengths between respondent subgroups.

	Residents [n = 66]	Faculty [N = 4]	*P value*
Overall (Std)	48% (9)	51% (21)	*0.33*
AP (Std)	16% (4)	21% (26)	*0.15*
Notch (Std)	18% (4)	16% (10)	*0.24*
Tangential (Std)	13% (4)	14% (8)	*0.84*
	Non-Trauma	**Trauma**	
Overall (Std)	48% (8)	51% (21)	*0.59*
AP (Std)	17% (4)	21% (26)	*0.52*
Notch (Std)	17% (4)	16% (10)	*0.72*
Tangential (Std)	14% (4.7)	14% (8)	*0.92*
	Residents [n = 66]	**Trauma faculty [n = 12]**	
Overall (Std)	48% (9)	51% (21)	*0.33*
AP (Std)	16% (4)	21% (26)	*0.15*
Notch (Std)	18% (4)	16% (10)	*0.24*
Tangential (Std)	13% (4)	14% (8)	*0.84*

When performing the standard intraoperative PA view of the knee, the X-ray beam is perpendicular to the coronal plane of the distal femur, resulting in the narrower anterior distal femoral cortex becoming superimposed on the broader posterior femoral condylar cortex [10]. This difference is further enhanced by magnification error. This results in difficult image interpretation, which was confirmed by our study. In our study, we demonstrated that our ability to interpret screw lengths using intraoperative fluoroscopy is quite poor, with the correct assessment ranging from 44 to 52%, depending on radiographic view. Likewise, there was no difference in accuracy between attending surgeons, residents, and physicians specifically trained in orthopaedic traumatology, suggesting that increased exposure to retrograde nailing does not result in more accurate measurement. This result was surprising to the authors, and emphasizes the need for methods to improve this measurement error.

Our findings suggest that the femoral notch view improves accuracy overall in assessing screw length when compared to the traditional PA (OR: 1.26; CI: 1.073–1.475; P < 0.005). Interestingly, screws that were placed “too long” were accurately assessed in 51.65% of cases using the PA view, versus 44.42% using the femoral notch view (OR: 0.73; CI 0.55−0.96; P < 0.025). However, sensitivity/specificity calculations revealed the PA view was marginally more sensitive and less specific than the femoral notch view (51.6% vs 50.5% sensitivity, 80% vs 87.1%. This suggests that the addition of the notch view would help ‘rule out’ too-long screws in equivocal cases using the PA view. This mirrors our clinical practice and anecdotal experience. In our practice, if a screw appears flush on the PA, a notch view is obtained to assess if the screw is too long. When we looked at individual participants in this study, 42% of participants who incorrectly identified a prominent screw as being the appropriate length on the PA view, chose correctly when utilizing the notch view, increasing their ability to detect long screws. This interpretation however is limited in that the images were not presented in tandem, rather individually, at random.

Other authors have attempted to improve accuracy by assessing screw lengths on the tangential view of the distal femur. Zheng et al. demonstrated that medial and lateral tangential views are superior at identifying distal interlocking screws discrepancies than the standard AP view [10]. We did not appreciate this in our

findings. Although our study found this was true for identifying screws 2-mm short, this view was not superior to the PA or Notch view for screws that were flush or 2-mm long, which are the screws we are trying to identify.

The amount of screw prominence that can be tolerated before becoming symptomatic is unknown. There may be a certain threshold to which screws that extend beyond the medial cortex are well tolerated. It is likely a confluence of factors, including body habitus, screw location and orientation of the nail (external vs internal rotation) may play a role in the development of symptoms. Hamaker et al showed that screws extending to or beyond the medial cortex were likely to be symptomatic [11]. This parallels our finding that screws which appear flush on the PA may in fact be prominent. Additionally, the authors demonstrated that screws within 40-mm from the joint line were more symptomatic [11].

There are some limitations of the present study that merit discussion. Our response rate was 75% from our online anonymous survey. This may lead to a sampling bias, however, in efforts to minimize bias, we sent this to 3 ACGME-accredited residency programs [14]. A survey of the community orthopaedic surgeon however, may lead to differing results. Additionally, we utilized two views which are not commonly utilized during trauma surgery. The survey participants may have been unfamiliar with interpreting these views, and further exposure to the views could improve accuracy. The strength of this study includes our large sample size, including over 3100 question responses. Additionally, incorporation of multiple training programs and subspecialties help broaden the generalizability of the findings.

Removal of symptomatic screws after femoral nailing is a common procedure. This may be related to difficulty in assessing screw length due to complex distal femoral geometry. Our ability to correctly assess screw length radiographically is quite poor. In our study, surgeons correctly assessed length in less than 50% of cases. Use of the femoral notch view significantly improves accuracy, but not entirely (5% improvement). Given the ease of use, the femoral notch view should be used in conjunction with the traditional PA view to maximize both the sensitivity and specificity for detecting prominent screws. Use of the femoral notch view combined with careful intraoperative radiographic assessment and surgical technique could decrease the need for symptomatic screw removal, thus decreasing the burden of trauma on the individual and society.

Conflict of interest statement

Boshen Liu, David Zuelzer, Jerad Allen, Shea Comadoll, and Eric Swart have nothing to disclose.

Joseph Hsu was a paid presented/speaker for Smith and Nephew. He is also a board or committee member of the Limb Lengthening Research Society. The terms of these arrangements have been reviewed and approved by Carolinas Medical Center in accordance with its policy on objectivity in research.

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