



Intra-medullary nail insertion accuracy: A comparison of the infra-patellar and supra-patellar approach

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ABSTRACT

Aims: The anatomical safe zone for intra-medullary nail insertion through the tibial plateau is small, insertion outside of this area risks damage to intra-articular structures and poor fracture reduction. The purpose of this retrospective study was to determine if the new supra-patella (SP) approach confers improved nail insertion accuracy, when compared with the standard infra-patella (IP) technique.

Patients and Methods: Two hundred cases were included in the study (SP 95, IP 105). Insertion accuracy was assessed on AP and lateral radiographic imaging, and measured as the distances between the central axis of the proximal nail and the ideal entry point.

Results: The median distance from the ideal entry point was 4.4 mm (SP) and 5.1 mm (IP) ($p=0.046$) in the coronal plane, and 4.0 mm (SP) and 3.7 mm (IP) ($p=0.527$) in the sagittal plane. A narrower range in measurements was observed in the SP technique in both sagittal and coronal planes, 17.8 mm vs 28.6 mm, and 19.7 mm vs 30.3 mm respectively.

Conclusion: We found that the SP technique achieved significantly improved nail insertion accuracy in the coronal plane. Insertion accuracy was equivocal between the two techniques in the sagittal plane. A narrower range in entry points was observed in the SP cohort in both planes suggesting improved control in nail insertion using this technique.

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Introduction

The supra-patella (SP) approach for intramedullary nailing (IMN) of the tibia was first described by Dean Cole, MD in 2006 [1]. The approach was developed as a modification of the semi-extended (SE) technique described by Tornetta and Collins in 1996 [2]. The primary benefit of operating in a semi-extended (15°) position, was the reduction of deforming forces acting on the proximal fracture fragment when operating on proximal tibial fractures [1,3] (Figs. 1 and 2). The SP approach replaced the large parapatellar incision required for the SE technique, with a small percutaneous entry point proximal to the patella through the skin and quadriceps tendon. Further benefits of both approaches include improved fluoroscopic/C arm access and the avoidance of repeated limb manipulation and subsequent loss of reduction [4–6]. The SP technique has also been shown to be superior to the IP in achieving intra-medullary nail insertion angles closer to the longitudinal access of the tibia, this reduces the risk of iatrogenic injury to the posterior cortex of the tibia and further aids the

avoidance of apex anterior displacement in proximal tibial fractures [7]. In our institution the SP approach has become the standard technique used by some surgeons for all fractures of the tibia treated with IM nailing.

The anatomical safe zone or 'sweet spot' for IMN insertion was described by Tornetta et al in cadaveric studies as a width of 22.9 ± 8.9 mm (range 12.6–56 millimeters), located 9.1 ± 5 mm lateral to the midline of the tibial plateau [8]. Radiographically the safe zone and ideal entry point is centered just medial to the lateral tibial spine on the anterior-posterior (AP) radiograph and immediately adjacent and anterior to the articular margin of the medial tibial plateau on lateral imaging [9]. The anatomical safe zone on the anterosuperior aspect of the tibial plateau is small, insertion outside of this area risks damage to intra-articular structures particularly the ligamentum transversum and medial meniscus [8,10]. Accuracy of nail insertion also improves fracture reduction with lateral and medial entry points causing varus and valgus deformity respectively [11]. Previous studies have suggested improved insertion accuracy via the SP approach vs the standard IP technique [12], these studies however used small cohort sizes (IP 38 vs SP 36).

The primary aim of this paper is to access tibial IMN insertion accuracy between IP and SP cohorts via retrospective radiographic analysis. This paper will be the largest comparative series to date.

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Fig. 1. Lateral radiograph demonstrating guidewire insertion via the infra-patellar approach with the knee in flexion.



Fig. 2. Lateral radiograph demonstrating guidewire insertion via the supra-patellar approach with the knee in semi-extension.

Our primary null hypothesis was that there would be no difference between approaches.

Methods

Data was collected at a central London level 1 major trauma centre (MTC). A retrospective analysis of prospectively collected data was conducted. All tibial IMN's undertaken between 01/2014 to 02/2018 were identified. Exclusion criteria included ipsilateral

tibial plateau fractures treated with open reduction and internal fixation and individuals that did not have appropriate post op imaging.

Patients were divided into two groups: those treated using the IP technique and those treated using the SP technique. All surgery was carried out either by or under direct supervision of a senior orthopaedic trauma consultant. The insertion technique used was determined at the discretion of the operating surgeon, as was the decision for any adjuvant intervention.

Nail insertion accuracy was assessed on review of intra-operative or immediate postoperative radiographic imaging, in both AP (coronal) and lateral (sagittal) views. The ideal entry point was defined as 2 mm medial to the lateral tibial spine on AP imaging and immediately adjacent and anterior to the articular margin of the medial tibial plateau on lateral imaging [9]. Measurements were calibrated using the 5 mm core diameter of the proximal locking screw. The nail entry point was defined as the point at which the central axis of the proximal nail transects the tibial plateau. The distance was measured (to the nearest 0.1 mm) between the ideal entry point and the observed entry point as described above. The direction of nail entry relative to the ideal entry point was also documented by giving medial/lateral entry points positive/negative values respectively, the same process was carried out for anterior/posterior entry points. All measurements were carried out by a blinded observer. A random sample of 20 cases were re-measured by a second independent observer using the same measuring technique to ensure accuracy and reproducibility.

Sample characteristics were tested for normality using the Shapiro-Wilk's test, visual inspection of their histograms, normal Q–Q plots and box plots. A Levene's test was used to assess equality of variance. Where data was normally distributed and equality of variance confirmed, significance was assessed using the independent samples 2-tailed *t*-test. Where data was not normally distributed, significance was assessed using the Mann-Whitney U test. For categorical data, difference between groups was assessed using a chi-squared test. Inter-observer correlations were calculated using Spearman rank correlation coefficient. Throughout this study a P-value of <0.05 was deemed significant. Statistical analysis was carried out using SPSS for Windows.

Results

A total of 210 operations were identified over the time period, 10 cases were subsequently excluded, 2 for ipsilateral displaced tibial plateau fractures and 8 for unavailable imaging. The infra-patellar (IP) group comprised 105 patients with a median age of 35 (IQR, 27), this compared to the supra-patellar (SP) group which comprised 95 patients with a median age of 45 (IQR, 31) (Table 1). Indications for surgery were categorised as acute trauma or reconstruction, in the IP group 96.2% of procedures were for acute trauma compared with 83.2% in the SP group ($p=0.002$). In the acute trauma cases 4.8% had initial management with external-fixation in the IP group compared with 16.8% in the SP group ($p=0.002$). Patient gender and rates of open injury showed no significant difference between the two groups.

Table 1

*Independent samples 2-tailed *t*-test or Students T-test, † Chi-Squared Test, ‡ Mann-Whitney U test.

	Suprapatellar Cohort	Infrapatellar Cohort	P value
Median age (yrs)	45 (16 to 92)	35 (17 to 91)	0.015*
Male : Female ratio	78:17 (82.1%)	82:23 (78.1%)	0.479†
Acute trauma : Reconstructive	79:16 (83.2%)	101:4 (96.2%)	0.002‡
Of acute trauma initial Ex-fix	16:63 (16.8%)	5:96 (4.8%)	0.002‡
Open fracture : Closed	42:37 (44.2%)	45:56 (42.9%)	0.251‡

In the IP group the mean entry point was 1.3 mm anterior (range 28.6 mm, Std. 5.4 mm) to the ideal entry point and 2.9 mm medial (range 30.3 mm, Std. 6.5 mm). In the SP group the mean entry point was 3.5 mm anterior (range 17.8 mm, Std. 4.0 mm) and 3.4 mm medial (range 19.7 mm, Std. 4.5 mm). A Levene's test verified heterogeneity of variance in the samples with P value of 0.008 on lateral measurements and 0.001 on AP measurements.

For the analysis of entry point accuracy, we aimed to assess the distance measured from the ideal entry point not the vector and subsequently all distances were converted to positive values. Analysis of sample characteristics as described above showed that the data did not exhibit normal distribution.

A significant difference in nail insertion accuracy was observed between the two groups in AP imaging (coronal plane) (Fig. 3) but not in the lateral (sagittal plane) (Fig. 4) (Table 2). In the AP images the median insertion point was 5.1 mm (IQR 8.3 mm) in the IP group compared to 4.4 mm (IQR 7.2 mm) in the SP group ($p=0.046$). In the Lateral images the median insertion point was 3.7 mm (IQR 6.5 mm) for the IP group compared with 4.0 mm (IQR 6.2 mm) in the SP group ($p=0.572$).

Inter-observer correlation was assessed by running a Spearman's rank-order correlation, this showed a strong, positive correlation which was statistically significant on both lateral ($r_s(8) 0.971, p=0.001$) and AP ($r_s(8) 0.991, p=0.001$) measurements.

Discussion

Our findings suggest that the supra-patellar technique confers improved nail insertion accuracy in coronal plane when compared to the standard infra-patellar approach. This finding is in partial agreement with the observations of Jones et al [12] whose study showed improved accuracy in both sagittal and coronal planes. The

main difference between the two papers, is the larger sample size used in our study (200 vs 74).

Interestingly, the mean entry point of nail insertion in the IP group was closer to 'ideal' in both coronal and sagittal planes. This finding however did not confer superior insertion accuracy as much greater variance was observed in the IP group. This finding supports the concept that the SP technique provides a more controlled environment for nail insertion, and it is this improved control that facilitates improved accuracy. Factors that contribute to improved surgical control include the ease of fluoroscopic access intra-operatively and the reduced need for limb manipulation [3–6]. Further benefits include the ability to use the femoral trochlear as a conduit for nail placement [2,13–16].

Limitations of the study include a lack of homogeneity between the two cohorts with the SP cohort having a significant difference in age, indication for surgery and initial ex-fix management. The increased numbers of reconstructive surgery and initial ex-fix management in the SP cohort can be explained by the preference of the SP technique amongst the specialist lower limb consultants in our institution. Complex fracture patterns which require initial external-fixation are by default inherited by more experienced/specialist consultants. The same sentiment explains the preponderance of revision and reconstructive procedures in the SP cohort. This poses a potential limitation of this study due to the added expertise of the consultants using the SP technique. It should be noted however that neither age, indication for surgery or primary management in external fixation alters the surgeon's ability to achieve accurate nail insertion.

The inherent variability of plain radiographic imaging mean that it is impossible to reliably achieve perfect AP and lateral radiographic views. Three-dimensional imaging using postoperative CT's would confer more accurate assessment but would also expose patients unnecessarily to significant radiation loads.

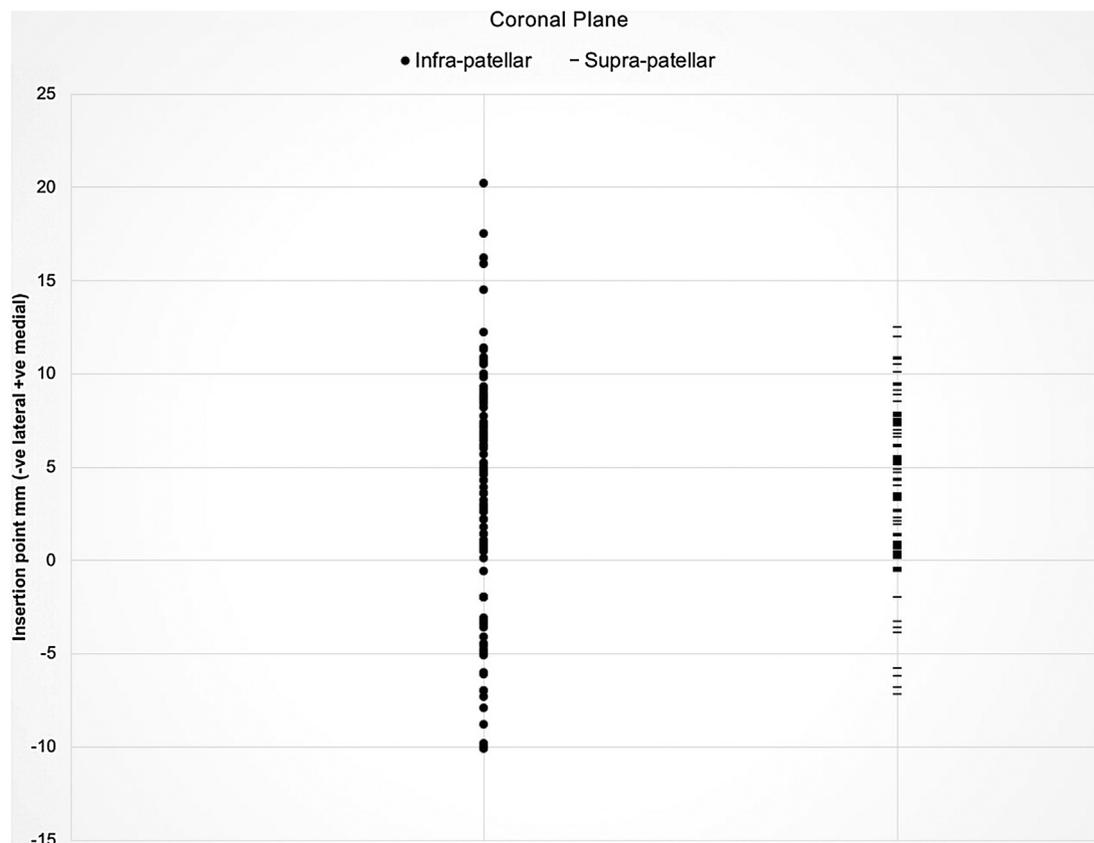


Fig. 3. Scatter graph showing nail insertion points in the coronal plane.

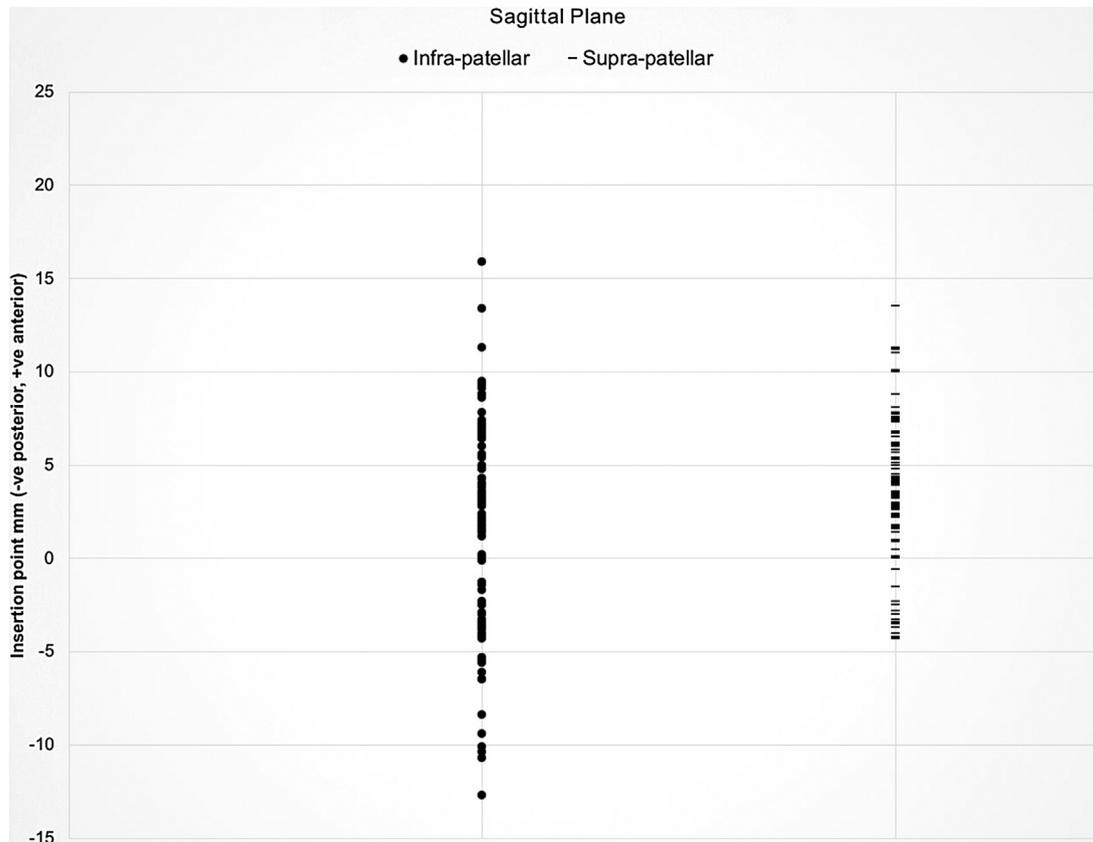


Fig. 4. Scatter graph showing nail insertion points in the sagittal plane.

Table 2

† Chi-Squared Test, ‡ Mann-Whitney U test.

	Infrapatellar group 1		Suprapatellar group 2		P Value
Median Distance From Ideal Entry Point Sagittal Plane	3.7 mm	(IQR 6.5 mm)	4.0 mm	(IQR 6.2 mm)	0.527 [†]
Median Distance From Ideal Entry Point Coronal Plane	5.1 mm	(IQR 8.3 mm)	4.4 mm	(IQR 7.2 mm)	0.046 [‡]

Though we acknowledge the limitations of plain radiographic imaging we believe that it can provide valuable assessment and also replicates the imaging resources available intra-operatively.

Accurate nail insertion has two main benefits; 1) it ensures improved fracture reduction [11] and 2) it ensures the avoidance of damage to intra-articular structures [8,10].

Critics of the supra-patellar approach highlight concern regarding damage to patellar femoral structures during instrumentation [10]. Peak contact pressures have been recorded up to 3 times higher (3.83 MPa) in the SP technique compared with the IP technique (1.26 MPa), however this is not felt to be significant as chondrocyte death does not reliably occur until a minimum pressure of 4.5 MPa is achieved [13]. Further to this by following proper surgical technique iatrogenic injury to patellofemoral cartilage can also be avoided.

Anterior knee pain is the most common symptom experienced by patients after tibial intra-medullary nailing, with rates as high as 86% reported in the literature following IP nail placement [17]. Anterior knee pain has a significant impact on quality of life as many individuals require the ability to kneel for both working and recreational purposes. Reduced rates of anterior knee pain have been reported by studies comparing the SP and IP technique [18,19], with Sanders et al reporting that no individuals experienced anterior knee pain in a series of 36

patients [1]. The cause of anterior knee pain is poorly understood and likely multifactorial; however, a number of hypothesized factors can be avoided via the SP approach including; injury to the infrapatellar branch of the saphenous nerve, splitting of the patellar tendon and damage to the retro-tendinous fat pad [20]. Furthermore, we propose that the SP approach can reduce the risk of damage to intra-articular structures due to improved nail insertion accuracy, achieving more reliable entry through the anatomical safe-zone.

In conclusion the SP approach has evolved from its initial purpose as a technique to overcome deforming forces in proximal tibial fractures, to a standard approach that allows easy C-arm access and reduced limb manipulation intra-operatively compared to the standard IP technique. Concerns regarding damage to the patella-femoral articular surface during instrumentation are noted however there is no available literature to support this viewpoint. Anterior knee pain is a common and distressing symptom experienced by patients post tibial intra-medullary nail insertion, rates of which are improved following SP nail placement when compared to the standard IP technique. Our paper agrees with previous studies that the SP technique confers improved nail insertion accuracy in coronal plane, with the consequent benefit of improved fracture reduction and avoidance of damage to intra-articular structures.

Conflict of interest statement

The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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