Research Square

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Postoperative Malalignment Following Reamed Intramedullary Nailing for Distal Tibia Fractures in Adults: A Prospective Observational Study

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Abstract

Purpose:

To determine the frequency of postoperative malalignment following reamed intramedullary interlocking nailing (IMILN) for distal tibia fractures and to evaluate its association with distal nail target (DNT) position, fracture morphology, and fibular fixation.

Methods:

This prospective observational study included 30 adults with distal tibia fractures extending within 11 cm of the tibial plafond who underwent reamed IMILN between August 2024 and May 2025 at a Level 1 tertiary care center in Nepal. DNT position was assessed intraoperatively using fluoroscopy in anteroposterior and lateral planes. Postoperative alignment was assessed using the lateral distal tibial angle (LDTA) and anterior distal tibial angle (ADTA). Malalignment was defined as a deviation of more than 5° from the normal values.

Results:

Postoperative malalignment occurred in 7 patients (23%). Among malaligned cases, coronal DNT position was central in 4 (57%) and non-central in 3 (43%), while sagittal positioning was central in 3 (43%), posterior in 3 (43%), and far posterior in 1 (14%). Transverse and oblique fracture patterns each accounted for 3 (43%) malaligned cases. Fibular fixation was performed in 6 patients, of whom 1 developed malalignment. Mean postoperative ADTA and LDTA were 82.3° ± 3.2° and 90.9° ± 3.3°, respectively. No statistically significant association was found between central and medial/lateral DNT placement and malalignment.

Conclusion:

Postoperative malalignment occurred in nearly one-quarter of patients undergoing distal tibia nailing. Posterior DNT positioning and transverse or oblique fracture patterns appeared more frequently associated with malalignment, while fibular fixation may contribute to maintaining alignment. Larger prospective studies with functional follow-up are warranted.

Introduction

Distal tibia fractures are complex injuries due to their subcutaneous location and close proximity to the ankle joint.[1] Although reamed intramedullary interlocking nailing (IMILN) offers a minimally invasive and biomechanically sound option, it is often associated with challenges in maintaining proper alignment, particularly in the distal segment.[2, 3] Malalignment remains a frequent complication, reported in 5–30%

of cases, and can result in poor functional outcomes, gait disturbances, and early post-traumatic arthritis. [1, 4]

Radiographic alignment is commonly evaluated using the Lateral Distal Tibial Angle (LDTA) on anteroposterior (AP) radiographs and the Anterior Distal Tibial Angle (ADTA) on lateral views. A deviation greater than 5° from the normal values (LDTA ~ 89°, ADTA ~ 80°) is considered clinically significant and indicative of malalignment.[5]

The Distal Nail Target (DNT), defined as the projected intersection of the nail's centerline with the tibial plafond, has recently been used as an intraoperative fluoroscopic marker in both coronal and sagittal planes to assess alignment, with its position potentially correlating with postoperative angular deformity.[6] However, only a few studies have explored this concept, and none have addressed it in the Nepalese population.

This study aims to assess the frequency of malalignment in distal tibia fractures treated with IMILN and investigate its association with DNT positioning, fracture pattern, and fibular fixation. The use of intraoperative fluoroscopic assessment of DNT, along with postoperative ADTA and LDTA measurements, forms the basis of our study.

Methodology

This prospective observational study was conducted in the Department of Orthopaedics at Level 1 Tertiary Care Center, Nepal, over a period of ten months from August 2024 to May 2025. Ethical approval was obtained from the Institutional Review Committee, and informed consent was taken from all participants prior to enrollment.

The sample size was calculated using the standard formula:

$N=Z^2pq/d2$

Using a Z value of 1.96 for a 95% confidence interval, an estimated prevalence (p) of 0.02 for distal tibial fractures based on previous literature, and a 5% margin of error (d = 0.05), the calculated sample size was 29.8. A total of 30 patients were enrolled using a convenient sampling method. Distal tibial fractures were defined as fractures with the distal extent of the fracture line located within 11 cm of the tibial plafond .[7] Patients aged 18 years and above with such fractures, treated with reamed intramedullary interlocking nailing (IMILN), were included in the study. Cases with associated fibular fractures, whether managed operatively or non-operatively, were also eligible. To maintain consistency in assessment, only fractures where the tip of the nail was positioned within 5 cm of the plafond were considered. Exclusion criteria included Gustilo-Anderson grade III open fractures, segmental or proximal tibial fractures, associated injuries to the ipsilateral limb, pelvis, or spine, pre-existing deformities, ankle arthritis, or prior surgical intervention on the affected limb. Intraoperatively, all patients underwent standardized fluoroscopic assessment in both AP and lateral planes. The anatomical axis was constructed using two mid-diaphyseal points proximal and distal to the fracture. The lateral distal tibial angle (LDTA) was measured between this

anatomical axis and the lateral articular margin of the plafond on AP view. The anterior distal tibial angle (ADTA) was measured between the anatomical axis and anterior articular margin on lateral view. Normal alignment was defined as 89° (LDTA) and 80° (ADTA) per Paley's criteria, with > 5° deviation considered malaligned.[5]

The distal nail target was determined where the extrapolated nail centerline intersected the plafond. In the coronal plane (AP view), this intersection point was categorized among five quadrants (far medial to far lateral) relative to malleolar width. Similarly, in the sagittal plane (lateral view), position was classified among five quadrants (far anterior to far posterior) relative to plafond depth.This group categorisation was similar to the study by **Brinkmann** et al., with slight variation in nomenclature of the different subgroups.[6]

This standardized protocol enabled consistent evaluation of both angular alignment and nail positioning across all cases.

Data collected included patient demographics, mode of injury, fracture morphology, fibular fixation details, DNT location, and angular measurements. The data were recorded in Microsoft Excel and analyzed using SPSS version 26. Continuous variables were analyzed using descriptive statistics. The Independent Sample t-test test was used to assess correlation between DNT and ADTA/LDTA. The Chi-square test was applied to determine the association between categorical variables such as fracture type, fibular fixation, and malalignment. A p-value of less than 0.05 was considered statistically significant.

The primary research question addressed by this study was: What is the frequency of malalignment in adult patients undergoing reamed IM nailing for distal tibia fractures, and how does it relate to the position of the distal nail target as observed on intraoperative fluoroscopy.

Results

Patient Cohort

The study cohort consisted of 30 patients with distal tibial fractures, with a male predominance (male-to-female ratio 6:1). Road traffic accidents(RTA) accounted for the majority of injuries (90%, n = 27), while the remainder resulted from low-energy mechanisms (10%, n = 3). (Table 1)

Table 1
Basic Demographics of the Patients Enrolled in the study

S.No	Age	Age group	Sex	Side involved	Distance of fracture line from plafond	Distance	Morphology of fracture	Fibula ORIF	Mode of injury
1	45	40–60	male	Right	10	5–11 cm	communited	TENS nail	RTA
2	41	40–60	Female	Right	9	5–11 cm	spiral	No	RTA
3	29	20–40	Female	Right	10	5–11 cm	oblique	No	RTA
4	29	20–40	Female	Right	10	5–11 cm	oblique	No	RTA
5	41	40–60	male	Right	10.5	5–11 cm	oblique	yes	RTA
6	34	20–40	male	Left	4.5	< 5cm	communited	yes	RTA
7	24	20–40	male	Left	5	< 5cm	communited	No	RTA
8	38	20–40	male	Right	9.5	5–11 cm	oblique	No	RTA
9	54	40–60	male	Right	7.5	5–11 cm	oblique	No	RTA
10	39	20–40	male	right	10	5–11 cm	transverse	No	RTA
11	50	40–60	male	left	11	5-11cm	spiral	Yes	RTA
12	66	60–80	Female	Right	7	5–11 cm	oblique	no	Slip and fall
13	40	40–60	male	Right	4.5	< 5cm	transverse	no	RTA
14	22	20–40	male	Right	8	5–11 cm	oblique	no	RTA
15	26	20–40	male	left	10	5–11 cm	transverse	no	RTA
16	35	20–40	male	right	6	5–11 cm	transverse	no	RTA

S.No	Age	Age group	Sex	Side involved	Distance of fracture line from plafond	Distance	Morphology of fracture	Fibula ORIF	Mode of injury
17	39	20–40	male	right	8	5–11 cm	transverse	no	RTA
18	38	20–40	male	right	11	5–11 cm	oblique	no	RTA
19	40	40–60	male	right	4	< 5cm	transverse	no	RTA
20	21	20–40	male	left	9	5–11 cm	spiral	no	RTA
21	26	20–40	male	left	7.5	5–11 cm	oblique	no	RTA
22	50	40–60	male	right	10	5–11 cm	transverse	no	RTA
23	45	40–60	Female	right	8	5–11 cm	spiral	yes	RTA
24	24	20–40	male	right	6.5	5–11 cm	oblique	no	RTA
25	66	60–80	male	left	9	5–11 cm	spiral	yes	RTA
26	43	40–60	male	right	5	< 5cm	oblique	no	Slip and fall
27	66	60–80	male	left	8	5–11 cm	oblique	no	Slip and fall
28	34	20–40	male	left	7	5–11 cm	spiral	yes	RTA
29	38	20–40	male	left	10	5–11 cm	transverse	no	RTA
30	35	20–40	Male	right	9	5–11 cm	transverse	no	RTA

Fracture Characteristics

Oblique fracture patterns were most common (40%, n = 12), followed by transverse (30%, n = 9), spiral (20%, n = 6), and comminuted (10%, n = 3) configurations. Fractures were located at a mean distance of 7.9 cm

from the tibial plafond (range: 4–11 cm), with 83% (n = 24) occurring 5–11 cm distal to the plafond and 17% (n = 5) within 5 cm. (Table 1)

Fibular Fixation and Alignment

Fibular stabilization was performed in 20% of cases (n = 6), with plating used in five cases and elastic stable intramedullary nailing (ESIN) in one. All cases with fibular plating maintained anatomical alignment, whereas the single ESIN-stabilized case developed malalignment (p = 0.02, Fisher's exact test). (Table 1)

Nail Positioning and Postoperative Alignment

In the coronal plane, nails were positioned centrally in 77% of cases (n = 23), medially in 13% (n = 4), and laterally in 10% (n = 3). Sagittal plane assessment demonstrated central placement in 77% (n = 23), posterior in 20% (n = 6), and far posterior in 3% (n = 1). Postoperative radiographic measurements revealed a mean anterior distal tibial angle (ADTA) of 82.3° (SD: 3.2°) and lateral distal tibial angle (LDTA) of 90.9° (SD: 3.3°). Malalignment, defined as > 5° deviation from normative values, was observed in seven patients (23%). (Table 2)

Table 2
Showing ADTA, LDTA, Occurrence of malalignment, and Position of DNT in AP and Lateral images.

S.No	Carm ADTA	C arm LDTA	Malalignment	DIstal Nail Target AP	Distal Nail Target lateral
1	89	83	yes	Center	Center
2	84	90	no	Center	Center
3	82	88	no	Lateral	Center
4	87	86	yes	Center	Center
5	82	88	no	Center	Center
6	84	93	no	Medial	Posterior
7	82	90.5	no	Center	Center
8	83	96	yes	Medial	Posterior
9	91	84	yes	Lateral	Posterior
10	84	92	no	Center	Center
11	80	93	no	Center	Center
12	82	91	no	Center	Center
13	78	92	no	Center	Posterior
14	80	92	no	Center	Center
15	81	92	no	Center	Center
16	74	89	yes	Center	Far posterior
17	88	90	yes	Center	Posterior
18	82	89	no	Center	Center
19	81	92	no	Center	Center
20	80	89	no	Center	Center
21	80	92	no	Center	Center
22	82	91	no	Center	Center
23	80	93	no	Center	Center
24	79	92	no	Center	Posterior
25	81	93	no	Center	Center
26	84	91	no	Center	Center
27	82	94	no	Medial	Center

S.No	Carm ADTA	C arm LDTA	Malalignment	DIstal Nail Target AP	Distal Nail Target lateral
28	80	93	no	Medial	Center
29	85	96	yes	Lateral	Center
30	82	93	no	Center	Center

Analysis of Malaligned Cases

Among malaligned fractures, coronal plane nail positioning was central in four cases (57%) and non-central in three (43%). Sagittal plane positioning was central in three (43%), posterior in three (43%), and far posterior in one (14%). Transverse and oblique fracture patterns were equally represented among malaligned cases (43% each, n = 3), with one comminuted fracture (14%).

Statistical Comparisons

For analysis, DNT groups were combined as 'Center' (n = 22) and 'Medial + Lateral' (n = 8) due to small sample sizes in the latter groups. ADTA showed a 2.4° greater mean value in the medial/lateral placement group (84.4°±4.6°) compared to the center placement group (82.0°±3.0°), though this difference did not reach statistical significance (p = 0.103 Cohen's d = 0.63, 95% CI [-0.5,5.3]). Similarly, the lateral distal tibial angle (LDTA) demonstrated minimal variation between groups (92.2°±4.9° vs 91.2°±2.7°, p = 0.477, Cohen's d = 0.27, 95% CI [-1.7,3.7]). (Table 3)

Table 3
Statistical analysis using t-test to assess differences in ADTA and LDTA among different nail placement groups(DNT)

Parameter	Placement Group	Mean ± SD	95% CI	t-value	p-value	Effect Size (Cohen's d)
ADTA (°)	Center	82.0 ± 3.0	[-0.5,5.3]	1.68	0.103	0.63
	Medial/Lateral	84.4 ± 4.6				
LDTA (°)	Center	91.2 ± 2.7	[-1.7,3.7]	0.72	0.477	0.27
	Medial/Lateral	92.2 ± 4.9				

The incidence of malalignment showed comparable rates between center (22.7%) and medial/lateral (25.0%) placement groups (p = 0.885), indicating no significant association between nail position and malalignment outcomes in this cohort. (Table 4)

Table 4
Malalignment incidence by nail placement position

Outcome	Center (n = 2)	Medial/Lateral (n = 8)	χ^2	p-value
Malalignment	5 (22.7%)	2 (25.0%)	0.02	0.885
Normal	17 (77.3%)	6 (75.0%)		

Discussion

Malalignment in distal tibia fractures is a common occurrence following reamed intramedullary interlocking nailing (IMILN), with reported rates ranging between 20–40% in various series.[2, 8, 9] In our study, the incidence was 23%, which is comparable to these published figures and highlights the ongoing challenge of maintaining alignment in this anatomically demanding region.

Fracture morphology played a significant role in influencing alignment. Transverse and oblique fractures were most commonly associated with malalignment, whereas spiral patterns showed lower rates of angular deviation. This observation is consistent with previous studies that have suggested simple fracture configurations are inherently unstable and more prone to displacement during nail insertion, in contrast to spiral fractures which provide relatively better rotational stability.[10–12]

The distal nail target (DNT) has not been widely discussed in the literature as a determinant of alignment. Prior reports have linked valgus malalignment to medialized nail positions and procurvatum deformities to posterior placement.[13–16] In our cohort, although statistical significance was not achieved, malalignment was more frequently observed with posterior or far posterior sagittal nail positioning, while central placement in both planes appeared to provide the most reliable alignment. This reinforces the importance of targeting the center of the plafond intraoperatively.

Fibular fixation appeared to have a protective effect in our series. Of the six patients who underwent fibular stabilization, only one developed malalignment, and all cases treated with anatomical plating maintained satisfactory alignment. This finding supports previous biomechanical and clinical evidence that fibular fixation enhances stability and helps maintain tibial reduction, particularly in fractures located close to the plafond.[17–21]

Fracture distance from the plafond has previously been reported as a risk factor for malalignment, with fractures occurring within 5 cm of the joint line more vulnerable due to short working length and metaphyseal flare. In our series, we did not observe a strong association, likely due to the relatively small number of such cases. Similarly, other factors such as timing of surgery could not be evaluated, though these have been shown in earlier work to contribute to loss of alignment.[6, 9, 22–26]

The mean postoperative anterior distal tibial angle (ADTA) and lateral distal tibial angle (LDTA) in our study were 82.3° and 90.9°, respectively, both close to normative values described by Paley.[27] Despite the measurable incidence of malalignment, overall alignment was maintained within acceptable ranges in most patients. The absence of statistically significant differences between central and eccentric DNT

groups may reflect the small sample size and reliance on plain radiographic measurements, which can underestimate subtle deviations.

This study has limitations, including the small sample size and lack of functional outcome assessment, which prevents us from correlating radiological malalignment with patient-reported recovery. In addition, intraoperative fluoroscopy, though standardized, may still introduce variability in categorizing distal nail position.

Conclusion

This study demonstrates that postoperative malalignment following reamed intramedullary nailing for distal tibia fractures is relatively common, occurring in over a quarter of cases. Malalignment was more frequently associated with eccentric distal nail target positions. Fibular fixation reduced the likelihood of malalignment. Optimizing nail placement and selectively fixing the fibula may significantly improve alignment outcomes in distal tibia fracture management. Larger prospective studies with longer follow-up and functional outcome assessment are needed to confirm these associations and refine strategies for preventing malalignment in this challenging fracture subset.

Declarations

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Data Availability

Data generated or collected is acquired by the corresponding author and will be provided upon request and not shared publicly as it includes patient's information and privacy. The experimental data and the simulation results that support the findings of this study are available in DOI: 10.1097/BOT.0000000000001358.

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Conflict of Interest:

The authors declare no potential conflicts of interest.

Author Contributions:

- B.B.N.: Concept, study design, data management, manuscript preparation and revision

- O.P.S.: Data management, manuscript review
- S.R.: Data collection, manuscript drafting
- N.S.: Data management, manuscript revision
- S.B.: Data management, manuscript review
- I.P.: Data collection, manuscript review
- P.K.: Data management, manuscript revision

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Figures

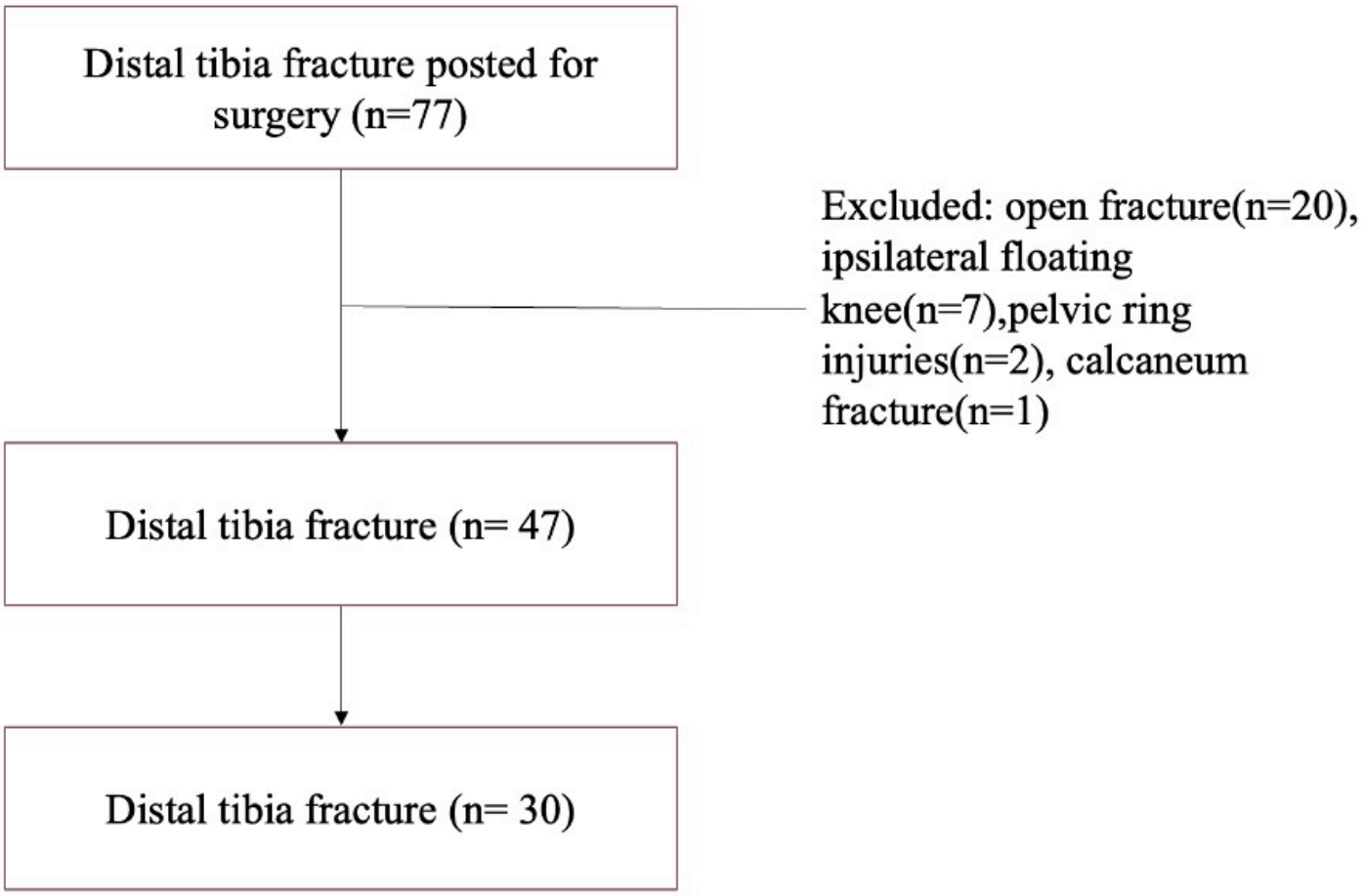


Figure 1

Flowchart showing the patient included in the study.

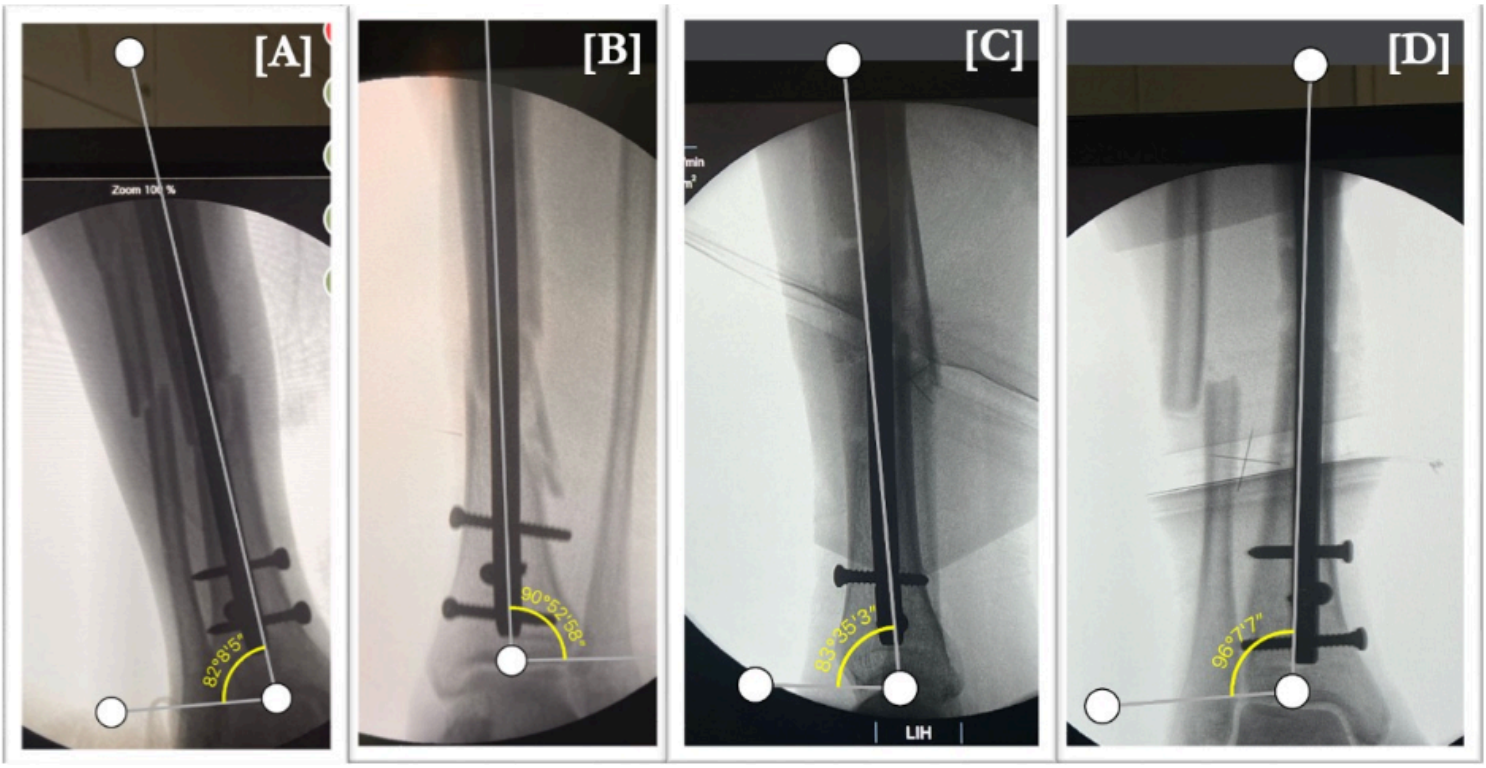


Figure 2

Methods of measurement of LDTA(A,B,D) and ADTA(C) using intraoperative fluoroscopy

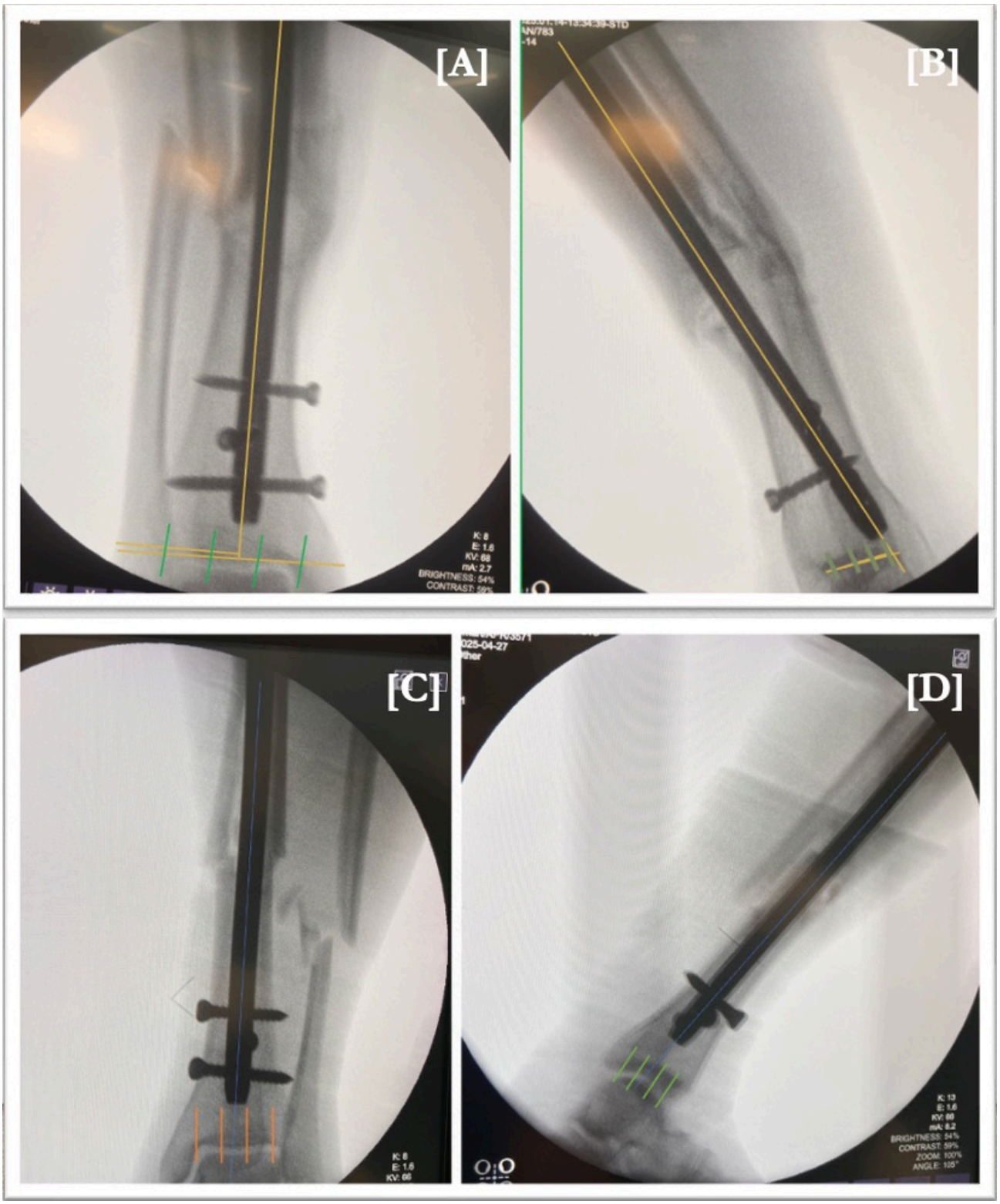


Figure 3

Method of measurement of DNT on AP and Lateral images of intraoperative fluoroscopy.