Open Access

Original Article

Tip Apex Distance as Predictor of Mechanical Complications in Unstable Intertrochanteric Fractures Treated with Proximal Femoral Nails

Muhammad Asif Rasheed, Muhammad Suhail Amin, Muhammad Nadeem Chaudhry, Malik Muhammad Haseeb, Muhammad Junaid, Kashif Ali Naz

Department of Orthopedics, Combined Military Hospital/National University of Medical Sciences (NUMS) Rawalpindi Pakistan

ABSTRACT

Objective: To evaluate the significance of Tip Apex Distance (TAD) as a predictor of mechanical complications in unstable intertrochanteric fractures treated with proximal femoral nails and to ascertain a cut-off TAD value for maintaining stable constructs.

Study Design: Cross-sectional analytical study.

Place and Duration of Study: Department of Orthopedics, Combined Military Hospital, Rawalpindi Pakistan, from Oct 2021 to Aug 2023.

Methodology: We assessed patient records for reduction categorized as per baumgartner's and Chang's criteria. We evaluated post operative radiographs for TAD and loss of reduction. We reviewed radiological follow ups at 3 months and 6 months to identify mechanical complications. We determined the statistical significance of TAD (p<0.05) and used receiver operating characteristic (ROC) curve to find the sensitive and specific cut-off value for TAD regarding mechanical complications.

Results: Among 132 patients, 12(9.09%) experienced mechanical complications. The mean age was 76.3±7.98 years, with 105 males (79.5%) and 27 females (20.5%). The mean TAD was 24.56±2.76 mm, and the mean calcar gap was 5.16±1.27 mm. We found a TAD cut-off of 24.5 mm to be 66.7% sensitive and 51.7% specific for predicting mechanical complications (AUC 0.55). Complications were significant in Cleveland zones: center-center (40.9%), inferior center (49.2%), and inferior posterior (9.9%) (p<0.001). The mean time to full weight-bearing without support was 21.00±1.22 weeks.

Conclusion: Maintaining a TAD of less than 25 mm when using the helical blade of intramedullary fixation devices is recommended. TAD is not an independent sole predictor of mechanical complications.

Keywords: Cephalomedullary nail, Fracture reduction, Pertrochanteric fracture, Secondary stability, Tip apex distance.

How to Cite This Article: *Rasheed MA, Amin MS, Chaudhry MN, Malik Haseeb M, Junaid M, Naz KA. Tip Apex Distance as Predictor of Mechanical Complications in Unstable Intertrochanteric Fractures Treated with Proximal Femoral Nails. Pak Armed Forces Med J 2024; 74(SUPPL-2): S179-S183. DOI: https://doi.org/10.51253/pafmj.v74iSUPPL-2.12248*

INTRODUCTION

Geriatric hip fracture poses significant challenges due to accompanying comorbidities.[1] The treatment aims to providing early mobility off bed and restore function so as to avoid well known complications related to prolonged immobility. Hip fractures are classified as per traditional Boyde griffin classification[2] and more recently prognostically significant AO classification system.[3,4] The unstable fracture patterns with increase in understanding in lieu of fracture mapping studies has led to improvement in surgical techniques. Recent focus on the comminuted postero-medial wall and lesser trochanter has introduced the concept of the anteromedial buttress.[5] The technique is utilized with a view to align fracture fragments in both anteroposterior and lateral views so as to prevent sliding upon initial weight bearing. Ideally a cortex-to-cortex buttress should prevent collapse as secondary stability.

Kauffer has explained five confounding factors for stability of constructs in extracapsular neck of femur fractures[6] i.e., quality of bone, fragment geometry, fracture reduction quality, implant selection and implant placement in the Cleveland zone. Baumgartner in his primitive study in 90's focused on providing a reduction quality criterion which till to date stays valid.[7] With slight modification and consideration of fracture fragment alignment, Chang's criteria is in practice in theatres with published results for less mechanical complications.[8] Baumgartner also provided a quantitative figure of cut-off tip apex distance (TAD) for the position of blade to signify the importance of getting a good purchase in subchondral bone. The value till to date is used both in extra-medullary as well as intramedullary fixation devices with a bird's eye view technique.[9] TAD refers to the sum of distance between the tip of the lag screw and apex of femoral head on anteroposterior and lateral views. This measurement serves as an indicator of the

Correspondence: Dr Muhammad Asif Rasheed, Department of Orthopaedics, Combined Military Hospital Rawalpindi Pakistan

Received: 05 May 2024; revision received: 05 Aug 2024; accepted: 07 Aug 2024

position of implant within the femoral head and is associated with biomechanical stability of construct. Being an indicator of improved biomechanical strength in an osteoporotic bone, the literature correlates optimal values with an improved outcome and fewer mechanical complications.[10]

The rationale of this study is to evaluate the risk of mechanical complications in unstable pertrochanteric fractures in the context of tip apex distance maintained while being operated with cephalomedullary nails. This study aims to correlate the cut-off value of TAD and its significance in creating a stable construct by utilizing intramedullary fixation i.e proximal femoral nail anti-rotation. By ascertaining the value of TAD in context of developed complications, we want to prognostically signify the optimal minimum TAD which should be achieved in all cases to prevent complications in an osteoporotic bone quality patient group. The chosen primary outcome measure signifying an impending mechanical complication is neck shaft angle (NSA) loss, as recommended in recent literature.[11]

METHODOLOGY

This retrospective analysis utilizes prospectively collected data from an ongoing trial in the Orthopaedics department of Combined Military Hospital, Rawalpindi, Pakistan, from Oct 2021 till Aug 2023. The hospital is the apex tertiary care teaching hospital of Government and serves as peer referral from Government as well as civilian colleagues for complex trauma cases. Hospital ethical review board approval was sought from committee vide approval letter no 1416/10/21 dated 23 Nov, 2021.

Sample size was calculated utilizing WHO sample size calculator taking confidence level 95%, margin of error 5% and reported prevalence of mechanical complications in neck of femur fractures 10%.[12] The estimated sample size came out to be 126 patients. Patients recruitment was as per purposive sampling technique.

Inclusion criteria: Patients with diagnosis of traumatic low energy hip fracture extracapsular, AO OTA classification 31A2.2, 31A2.3, age >60 years were included in the study.

Exclusion Criteria: High energy fractures and pathological fractures were excluded from the study. Inadequate clinical or radiological follow up patients were also excluded from the study group.

The implant utilized for intramedullary fixation was Proximal femoral nail anti-rotation, (7S Medical, PERICLES II Proximal femoral nail 125 degrees, Spiral Blade, 4.9mm locking screw torx, in static mode). We obtained Informed consent for all patients enrolled in this study. All patients were operated on traction table with standard position of fluoroscopic C arm for intra-operative assessment of fracture. `Greater trochanter entry point was made, long nails is a routine practice in our setup with view to improve biomechanical strength. The position achieved, calcar gap, nail diameter/ length, blade length, Cleveland zone for blade and tip apex distance TAD was measured per-operatively and endorsed in data log. Reduction was categorized utilizing Baumgartner's and Chang's criteria. We mobilized patients on first post operative day with legs hanging bedside, ankle pumps and weight bearing with an assisted device as tolerated. Discharge of patients was planned as per discretion of physician and usually on second post operative day.

Patients' data was retrieved from ongoing trial whereby radiological measurements were underway at 3 and 6 months to detect loss of neck length (NL), loss of neck shaft angle (NSA) and any gross mechanical complications. The construct was considered to have mechanical complication if there was gross cut in, cut out, cut through or implant breakage. Construct was also considered to have potentially mechanical complication if the NSA loss was greater than 10 degrees and NL loss was greater than 10 mm at 06 months. Functional score calculated was retrieved for all available patients for follow up.

Statistical Package for Social Sciences for Mac 24 (Released 2016. IBM SPSS Statistics for Mac, Version 24.0; IBM Corp, Armonk, NY) was used for data analysis. Quantitative variables were expressed as mean±Sd deviation and qualitative variables were expressed as frequency/percentages. Neck shaft angle loss, neck length loss and tip apex distance were compared utilizing an independent sample T-test. Cross tabulation and analysis were performed for reduction quality and Cleveland zone in reference to developed mechanical complications utilizing the chi-square test. A *p*-value of less than or equivalent to 0.05 was considered significant. Receiver operating characteristic (ROC) for TAD in reference to mechanical complications was calculated depicting the optimal sensitive and specific values for TAD.

RESULTS

During period October 2021 till Aug 2023, 202 patients were operated upon utilizing the protocol of ongoing study. Six (06) months follow up revealed a documented mortality in 39 (19.3%) patients, 31 (15.3%) patients lost to follow up who were unreachable on provided contact details on first or second visit and were excluded from study. Remaining 132 patients records were available with complete radiological follow-up for mechanical complications. 12 out 132 (9.1%) developed mechanical complications all being impending, none of the gross complication was encountered in 6 months.

The demographics with reference to developed mechanical complications are depicted in table-I.

Table I : Demographics of patient characteristics (n=132)

Variable	Mean+SD/ n(%)	With complication n=12	Without complication n=120	*p*-value
Age (Years)	76.32+7.98	81.0+7.69	75.8+7.89	0.795*
Gender				
Male	105(79.5%)	9(8.6%)	96(91.4%)	0.682**
Female	27(20.5%)	3(11.1%)	24(88.9%)	
Comorbidities				
Diabetes	54(41%)	5(9.3%)	49(90.7%)	0.937**
Hypertension	64(48.4%)	6(9.4%)	58(90.6%)	
Ischemic heart disease	7(5.3%)	0	7(100%)	
CVA	7(5.3%)	1(14.3%)	6(85.7%)	
AO type				
A2.2	67(50.8%)	8(11.9%)	59(88.1%)	0.470**
A2.3	65(49.2%)	4(6.2%)	61(93.8%)	
Baumgartner's				
Good	72(54.5%)	0	72(100%)	<0.001**
Satisfactory	48(36.3%)	0	48(100%)	
Poor	12(9.2%)	12(100%)	0	
Chang's				
Excellent	66(50%)	0	66(100%)	<0.001**
Acceptable	60(45.5%)	6(10%)	54(90%)	
Poor	6(4.5%)	6(100%)	0	
Cleveland Zone				
Centre-Centre	54(40.9%)	0	54(100%)	<0.001**
Inferior-Centre	65(49.2%)	6(9.2%)	59(90.8%)	
Inferior-Posterior	13(9.9%)	6(46.1%)	7(53.9%)	
Tip Apex Distance(mm)	24.56+2.76	25.1+2.75	24.5+2.76	0.921*
Calcar Gap (mm)	5.16+1.27	8.50+0.52	4.83+0.73	0.815*
NSA Loss(mm)	6.45+2.09	11.5+0.52	5.95+1.41	<0.001*
NL Loss(mm)	6.50+1.06	12.3+0.75	5.55+1.10	<0.001*

Independent sample t-test. *
Pearson's Chi square test (p-value<0.05 significant
SD: Standard Deviation, CVA: Cerebrovascular Accident, AO: Arbeitsgemeinschaft für Osteosynthe-sefragen, NSA: Neck Shaft Angle, NL:Neck length

The mean age of the sample was 76.32±7.98 years (range: 65-102 years). Patients were classified into A2.2 (50.8%) and A2.3 (49.2%) fracture types. Total no of mechanical complications were encountered in 12 cases (9.09%). All 12 cases were radiologically potentially construct collapse as defined in operational definition. Mean neck shaft angle loss was 6.45 mm+2.09 and neck length loss was 6.54+1.06 and was significantly lost in mechanical complications group. (p<0.001). The mean time to full weight bearing without support was 21.00+1.22 weeks. Calcar fracture gap after achieved reduction was 5.16+1.27 mm and was not statistically significant in terms of mechanical complications (p-value=0.815). Cleveland zone centre-centre intent was executed but was achieved in 54 (40.9%) cases. About 65 cases (49.2%)ended up with inferior-centre and 13 (9.9%) cases in inferior-posterior Cleveland zone.

Mean Tip apex distance achieved was 24.56+2.76 mm. The TAD for group with mechanical complications and without mechanical complications was not statistically significant. (p-value 0.921). The AUC was found to be 0.55. The ROC curve shows no significant association between the tip apex distance and development of mechanical complications. (Figure-I) At a cut off value of 24.50mm, the value was 66.7% sensitive and 51.7% specific as per coordinates of the curve.

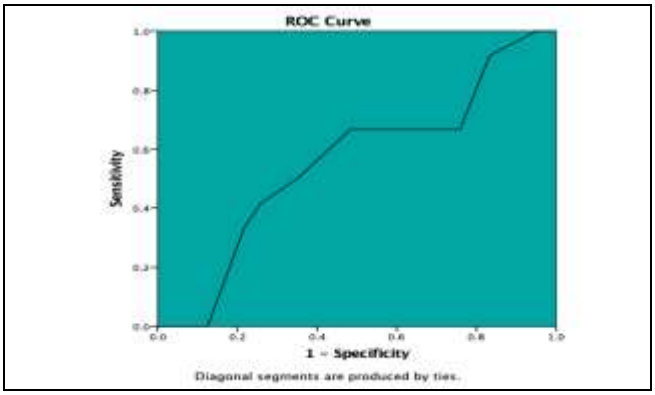

Figure-I: ROC curve for TAD with reference to developed mechanical complications (n=132)

DISCUSSION

Mechanical complications pose significant challenges in orthopedic practice, especially in patients with osteoporotic bone requiring early mobility.[13] The available literature revolves around preventing mechanical cut out or impending cut outs in patient who already have osteoporotic bone and need early mobility off bed.[14] The complication

hinders a smooth functional return to normal and thus increases morbidity as well as hospital expenditure. Although the current study is a retrospective study, but the data collected is prospective in a trial and purposefully evaluated the radiological outcome over 2 years.

Baumgartner first introduced the concept of TAD, recommending a cutoff of 25 mm for optimal outcomes. Subsequently studies explored this aspect and added calcar TAD concept in determining cut-outs. The calcar-TAD was first coined by Kuzyk *et al* in 2012 who defined it as a distance between lag screw tip and femoral calcar.[15] However superiority couldn't be established till today in comparison to traditional TAD. In a paper published by Rubio-Avila *et al*. patients with TAD >25 mm had significant increased risk of mechanical complication (mean difference 6.54mm between with and without complications)[16] Contrarily, Stern *et al* published results with no role of TAD as significant and other factors might be responsible for mechanical complications.[17] (RR=1.3, 95% CI 0.8–2.1).

Our study showed that the TAD has no statistical corelation with development of mechanical complications while other cofactors e.g. reduction quality, Cleveland zone placement might have more significant corelation to development of mechanical complications. The anteromedial cortical support (Chang's), acting as a secondary stability seems the key factor other than the placement in appropriate Cleveland zone. As far as Cleveland zone is concerned, literature published reveals that placement in upper quadrants increases the risk.[18-21] So far accepted position as recommended by AO is centre-centre owing to sliding of blade along the axis of blade upon initial weight bearing protocols. There is no role of delaying weight bearing protocol so to achieve a sense of stability and union where by the complications can be avoided. We have advocated all cases to be on touch down weight bearing with assisted devices from day 1 in our setup. That is probably due to the fact that we focuss on the details of reduction quality, Cleveland zone, a TAD <25mm and an optimal calcar gap at fracture site.

Several authors claimed that Baumgartner's TAD value can be increased and still outcome can be optimal. Yam *et al* published 27 mm cut-off. There are other studies which claim that cut-off of 25 mm has no role at all and it has no biomechanical justification.[22-24] In our study, our mean has been less than 25, this is probably due to the fact that we were always keen to have it less than 25 mm as a practice in our department as a principle for unstable intertrochanteric fractures. The ROC curve is parallel to 45 degrees diagonal and area under curve is 0.55. we still had 12 cases of mechanical impending complications which can be explained by association to other factors found in the analysis of data.

Limitations. This study is limited by the bias associated with retrospective studies, and the fact that data are based on the small number of potential mechanical complications in our study. Human errors in calculations of TAD should also be considered as a potential limitation of this study as all calculations were made on post operative radiographs. Furthermore, in lieu of evolving evidence for keeping other parameters strict, future studies might focus by strict randomization to ascertain a maximum limit of TAD that can be achieved without having impact on construct collapse.

CONCLUSIONS

In conclusion, to reduce mechanical complications in 31A2.2 and 31A2.3 fractures, it is crucial to maintain a TAD of less than 25 mm, ensure careful reduction, and align fragments according to Baumgartner's and Chang's criteria. The sensitivity and specificity of TAD in minimizing mechanical complications are critical and should be addressed along with other factors influencing construct stability during initial weight-bearing protocols. Our study highlights the importance of TAD and reduction quality in managing unstable intertrochanteric fractures. Future research should aim to establish the optimal TAD limit through randomized studies, considering other parameters influencing construct stability.

Conflict of Interest: None.

Funding Source: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MAR & MSA: Study design, drafting the manuscript, data interpretation, critical review, approval of the final version to be published.

MNC & MMH: Data acquisition, data analysis, approval of the final version to be published.

MJ & KAN: Critical review, concept, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Kanis IA, Oden A, McCloskey EV. A systematic review of hip fracture incidence and probability of fracture worldwide. Osteoporos Int 2012; 23: 2239–56.
2. Browner BD, Jupiter JB, Krettek C, Anderson PA. Intertrochanteric Hip Fractures. In: Skeletal Trauma: Basic Science, Management, and Reconstruction. Amsterdam: Elsevier, 2015: 1683–1720.
3. Kellam JF, Meinberg EG, Agel J. Fracture and Dislocation Classification Compendium-2018: International Comprehensive Classification of Fractures and Dislocations Committee. J Orthop Trauma 2018; 32: S1–170
4. Hsu CE, Chiu YC, Tsai SH. Trochanter stabilising plate improves treatment outcomes in AO/OTA 31-A2 intertrochanteric fractures with critical thin femoral lateral walls. Injury 2015; 46: 1047–53
5. Chang SM, Wang ZH, Tian KW, Sun GX, Wang X, Rui YF. A sophisticated fracture classification system of the proximal femur trochanteric region (AO/OTA-31A) based on 3D-CT images. Front Surg 2022; 9: 919225. http://doi: 10.3389/fsurg.2022.919225
6. Kaufer H. Mechanics of the treatment of hip injuries. Clin Orthop Relat Res 1980; (146): 53-61.
7. Baumgaertner MR, Curtin SL, Lindskog DM. Intramedullary versus extramedullary fixation for the treatment of intertrochanteric hip fractures. Clin Orthop Relat Res 1998; 348: 87-94
8. Chang SM, Zhang YQ, Ma Z, Li Q, Dargel J, Eysel P. Fracture reduction with positive medial cortical support: a key element in stability reconstruction for the unstable pertrochanteric hip fractures. Arch Orthop Trauma Surg 2015; 135(6): 811-8. http://doi: 10.1007/s00402-015-2206-x.
9. Baumgaertner M, Curtin S, Lindskog D, Keggi J. The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. J Bone Joint Surg [Am] 1995; 77-A:1058-1064.
10. Li S, Chang SM, Niu WX, Ma H. Comparison of tip apex distance and cut-out complications between helical blades and lag screws in intertrochanteric fractures among the elderly: a meta-analysis. J Orthop Sci. 2015; 20(6): 1062-9. http://doi: 10.1007/s00776-015-0770-0.
11. Marmor M, Guenthner G, Rezaei A, Saam M, Matityahu A. Reporting on quality of reduction and fixation of intertrochanteric fractures-A systematic review. Injury 2021; 52(3): 324-329. http://doi: 10.1016/j.injury.2021.02.014.
12. Ehlinger M, Favreau H, Eichler D, Adam P, Bonnomet F. Early mechanical complications following fixation of proximal femur fractures: From prevention to treatment. Orthop Traumatol Surg Res 2020; 106(1S): S79-S87. http://doi: 10.1016/j.otsr.2019.02.027. Kim SJ, Park
13. HS, Lee DW. Complications after internal screw fixation of nondisplaced femoral neck fractures in elderly patients: A systematic review. Acta Orthop Traumatol Turc 2020; 54(3): 337-343. http://doi: 10.5152/j.aott.2020.03.113.
14. Caruso G, Corradi N, Caldaria A, Bottin D, Lo Re D, Lorusso V, Morotti C, Valpiani G, Massari L. New tip-apex distance and calcar-referenced tip-apex distance cut-offs may be the best predictors for cut-out risk after intramedullary fixation of proximal femur fractures. Sci Rep 2022; 12(1): 357. http://doi: 10.1038/s41598-021-04252-1.
15. Kuzyk PR, Zdero R, Shah S, Olsen M, Waddell JP, Schemitsch EH. Femoral head lag screw position for cephalomedullary nails: a biomechanical analysis. J Orthop Trauma 2012; 26(7): 414-21. http://doi: 10.1097/BOT.0b013e318229acca.
16. Rubio-Avila J, Madden K, Simunovic N, Bhandari M. Tip to apex distance in femoral intertrochanteric fractures: a systematic review. J Orthop Sci 2013; 18(4): 592-8. http://doi: 10.1007/s00776-013-0402-5.
17. Stern R, Lübbeke A, Suva D, Miozzari H, Hoffmeyer P. Prospective randomised study comparing screw versus helical blade in the treatment of low-energy trochanteric fractures. Int Orthop 2011; 35(12): 1855-61. http://doi: 10.1007/s00264-011-1232-8.
18. Pascarella R, Fantasia R, Maresca A, Bettuzzi C, Amendola L, Violini S, Cuoghi F, Sangiovanni P, Cerbasi S, Boriani S, Tigani DS. How evolution of the nailing system improves results and reduces orthopedic complications: more than 2000 cases of trochanteric fractures treated with the Gamma Nail System. Musculoskelet Surg 2016; 100(1): 1-8. http://doi: 10.1007/s12306-015-0391-y.
19. Li J, Zhang L, Zhang H, Yin P, Lei M, Wang G, et al. Effect of reduction quality on post-operative outcomes in 31-A2 intertrochanteric fractures following intramedullary fixation: a retrospective study based on computerised tomography findings. Int Orthop 2019; 43(8): 1951–9.
20. Jia X, Zhang K, Qiang M, Chen Y. The accuracy of intra-operative fluoroscopy in evaluating the reduction quality of intertrochanteric hip fractures. Int Orthop 2020; 44(6): 1201–8.
21. Song H, Chang SM, Hu SJ, Du SC. Calcar fracture gapping: a reliable predictor of anteromedial cortical support failure after cephalomedullary nailing for pertrochanteric femur fractures. BMC Musculoskelet Disord 2022; 23(1): 175. http://doi: 10.1186/s12891-021-04873-7.
22. Yam M, Chawla A, Kwek E. Rewriting the tip apex distance for the proximal femoral nail anti-rotation. Injury 2017; 48(8): 1843-1847. http://doi: 10.1016/j.injury.2017.06.020.
23. Goffin JM, Jenkins PJ, Ramaesh R, Pankaj P, Simpson AH. What is the relevance of the tip-apex distance as a predictor of lag screw cut-out? PLoS One. 2013 Aug 28; 8(8): e71195. doi: 10.1371/journal.pone.0071195.
24. Buyukdogan K, Caglar O, Isik S, Tokgozoglu M, Atilla B. Risk factors for cut-out of double lag screw fixation in proximal femoral fractures. Injury. 2017; 48(2): 414-418. http://doi: 10.1016/j.injury.2016.11.018.