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Original Research Article

Fixation stability scoring in inter-trochanteric femur fractures treated with osteosynthesis: A retrospective observational study

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ABSTRACT

Objective: To find out the validity of a newly proposed fixation stability scoring system in IT fractures treated with osteosynthesis and its limitations if any.

Materials and Methods: Retrospective analysis of hospital records of patients with various types of intertrochanteric fractures treated surgically at Sri Siddhartha medical college, Tumkur from January 2021 till August 2022. The exclusion criteria were non-ambulatory patients prior to fall, non surgically treated patients, patients loosing follow up or patients who are not alive at the time of study. The scoring was done by three different observers for each patient's immediate post operative x-ray, repeated at 1 month interval. Radiographs at the final follow up were assessed for fracture union or fixation failure. Parameters of the scoring system: 1) cortical buttress in AP view radiograph, 2) cortical buttress in lateral view radiograph, 3) Tip apex distance (TAD) of principle lag screw, 4) Entry point (in case of IM nail), 5) Location of tip of principle screw in the desired Cleveland zone. 6) Placement of Richard screw in the inferior half of neck (in case of DHS), 7) Use of additional derotation screw (DRS) (in case of DHS).

Results: Scores of all the observers showed statistically significant correlation with fixation failure rates. Results were good with the score of 7.5 and above, fair with 6.5 and above and poor when the score was below 6.5. The minimum acceptable score was 6.5 for extra-medullary devices and 7 for intra-medullary devices.

Conclusion: The newly proposed scoring system appears to be valid and promising intra operative guide for fixation of intertrochanteric fractures with a few limitations. Large scale multi centre prospective studies are needed in the future to support the current study or to further simplify this scoring system.

1. Introduction

Inter-trochanteric (IT) femoral fractures are common in the elderly & the most common offered treatment is surgical stabilisation. The devices used for osteosynthesis are DHS, PFN, PFNa, PFNa2, AFN, Gamma nail, Inter-tan nail etc. Anatomical reduction and stable fixation remain the key principles in surgical management irrespective of the type of fracture and the device used. There is significant amount of controversy regarding adequacy of reduction, preferred device and fixation skill in the existing literature with many authors relying on one or two points to come to a conclusion of good surgery. Having felt that an intraoperative guide is necessary for a happy and confident post operative management of these patients, we subsequently formulated a new scoring system including almost all the key points and retrospectively analysed the patients and their post operative x-rays for stability of fixation, time to mobilisation, complications, fixation failures and revision surgeries. Therefore, the objective of

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this study was to find out the validity of a newly proposed fixation stability scoring system in IT fractures treated with osteosynthesis and its limitations if any.

2. Materials and Methods

In a retrospective manner we analysed the case records of patients with various types of intertrochanteric fractures treated at our hospital from January 2021 till August 2022. The exclusion criteria were 1) non-ambulatory patients prior to fall, 2) Non surgically treated patients, 3) patients loosing follow up or patients who are not alive at the time of study. In total we enrolled 37 patients overall after excluding 4 of the 41 intertrochanteric fracture patients screened for study eligibility. Demographic details can be seen in Table 2 below. Mean follow up period was 6 months. Fractures were classified based on AO classification. All types of intertrochanteric fractures were included irrespective of their stability. All patients had closed reduction and internal fixation. All were made to sit on bed within first week of surgery, to stand and walk with the help of walker from post op 1 to 4 weeks based on patient's general condition. Immediate post operative X-rays (final C-arm images in some cases) were assessed by our technique-oriented fixation stability score system (Table 1). A total of 7 parameters were chosen. 1) cortical buttress in AP view radiograph, 2) cortical buttress in lateral view radiograph, 3) Tip apex distance (TAD) of principle lag screw, 4) Entry point (in case of IM nail), 5) Location of tip of principle screw in the desired Cleveland zone. 6) Placement of Richard screw in the inferior half of neck (in case of DHS), 7) Use of additional derotation screw (DRS) (in case of DHS). For the establishment of fracture stability, the accurate opposition of anteromedial cortical buttress was considered to be the most important factor. Many authors have proved that valgoid reduction of anteromedial cortex with positive cortical buttress is superior to neutral reduction in achieving union on weight bearing.[1–3] Hence, we set maximum score i.e., 3points each for cortical buttress in AP and lateral view x-rays. TAD is useful intra operative indicator and that a TAD of <25mm had been shown to be generally predictive of a successful result in DHS as well as intramedullary devices.[4–7] Hence, we allotted 2 points for TAD <25mm irrespective of the fixation type. 1 point was allotted for TAD >25mm. The medial trochanteric entry point results in early hip function recovery and achieves excellent nail positions with fewer impingements, lower principle screw position and fewer surgical complications.[8,9] Location of tip of the lag screw at the Cleveland zones 5,6,8 & 9 has proved least chances of screw cut out anterosuperiorly.[10] 1 point was set for each of these parameters. Inferior locations of the principle screw in DHS helps to support the medial cortex and calcar femorale subsequently reducing the risk of cut out failure.[11] Also using additional derotation screw in the upper half of neck improves the rotational stability of the fracture.[12] The sliding components of the DHS allow solid fixation of the two major fragments in two planes with the DRS rather than the uncontrolled impaction in the third plane.[12] Each of these parameters were given $\frac{1}{2}$ point with an intention to limit the maximum score to 10.

The scoring was done for each patient's immediate post operative x-ray, least possible score being 3 and maximum score 10. Patients who lost follow up or died were excluded from the study. All patients were contacted by either direct consultation or telephonic conversation. Each patient's most recent post operative x-ray (AP and lateral views) was procured and the fracture union was assessed by the sealing callus on all around the cortices including anterior, medial, posterior and lateral surfaces. The presence of calluses on 3 cortices was deemed as evidence of union. The fracture was considered to have a failed fixation when there was over 5° varus collapse of the neck-shaft angle or cut-out of lag screw through the femoral head, penetration of screw into the hip joint or lag screw back-out (or z effect, reverse z effect) or internal fixation device failure or if there is already a revision fixation. Enquiry was made about time to mobilise independently, functional improvement in terms of ADL and return to work, current complaints, complications and any revision surgeries. The results were tabulated and statistically analysed using SPSS software ver 24.

2.1. Statistical analysis

The fixation failure rate at each score was calculated, and correlations between the failure rate and each score were analyzed using Spearman's correlation. The Spearman's correlation coefficient (r) was interpreted as poor if < 0.30, fair if 0.31–0.50, moderate if 0.51–0.60, moderately strong if 0.61–0.80, and very strong if ≥ 0.81. The fixation failure rate, based on the assessed scores in subgroups was compared using Fisher's exact test. In addition, the current authors analyzed the difference in the stability score using one-way ANOVA and failure rate using Fisher's exact test among the different types of implants. An intraclass correlation coefficient (ICC) was calculated for assessment of the intraobserver and inter-observer reliability. The scores of all 37 patients were measured in one month intervals by 3 orthopaedic surgeons for the evaluation of inter-observer and intraobserver reliability. A p-value of <0.05 was considered as statistically significant. This study was approved by the Institutional Review Board of Sri Siddhartha Medical college & research centre, Tumkur.

Mean age of the patients was 63 years 8 months (30 to 85yrs). Fixation failure was observed in totally 8 patients (21.6%, 5 males, 3 females). Among them, Fixation failed in 2 out of 12 patients with A1 type, 2 out of 19 patients with A2 type and 4 out of 6 patients with A3 type fractures respectively. Main type of failure was varus collapse with

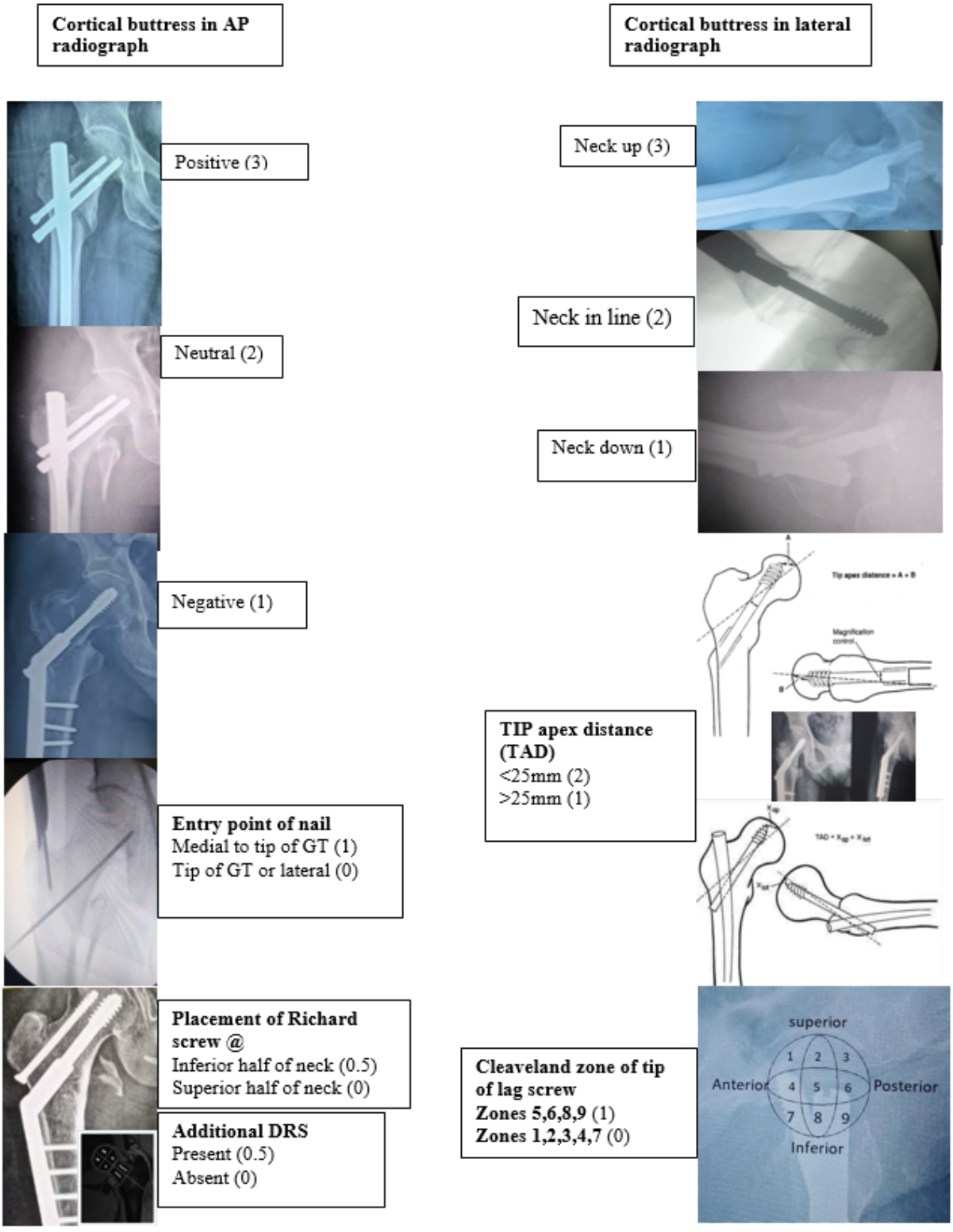


Fig. 1: Illustrative images of parameters of the scoring system

Table 1: Fixation stability scoring system in IT fractures

1	Cortical Buttress in AP view xray	Positive buttress	3 points.
		Neutral buttress	2 points.
		Negative buttress	1 point.
2	Cortical Buttress in lat view xray	Neck up	3 points.
		Neck in line	2 points.
		Neck down	1 point.
3	TAD of Principle/ lag screw/Richard screw (AP & Lat X-ray combined)	</= 25mm	2 points.
		> 25mm	1 point.
4	Entry point (In case of Nail)	Medial to tip of GT	1 point.
5	Location of tip of lag screw in the Cleveland zones	5,6,8,9	1 point.
		Other than 5,6,8,9	0 point.
6	DHS	Richard screw @ lower half of neck of femur	$\frac{1}{2}$ point.
		@ upper half of neck of femur	0 point.
7	DHS + DRS	Additional Derotation screw present	$\frac{1}{2}$ point.
		Derotation screw absent	0 point.
	Total possible score for an ideal fixation - 10.		

Table 2: Demographic details

Category		DHS	DHS+ DRS	PFN Short	PFN long	AFN/Gamma Nail	PFNA2	Total (%)
Males (%)		4	0	9	4	1	1	19(51.4%)
Females (%)		0	2	9	6	0	1	18(48.6%)
Side	Right	1	2	8	5	1	0	17(45.9%)
	Left	3	0	10	5	0	2	20(54.1%)
AO type Stable (n18)	A1.1	2	0	0	0	0	0	02(5.4%)
	A1.2	2	1	4	0	0	0	07(18.9%)
	A1.3	0	0	2	0	0	1	03(8.1%)
	A2.1	0	1	5	0	0	0	6(16.2%)
	A2.2	0	0	6	0	0	0	6(16.2%)
Unstable type (n19)	A2.3	0	0	1	4	1	1	7(18.9%)
	A3.1	0	0	0	2	0	0	2(5.4%)
	A3.2	0	0	0	0	0	0	0(0%)
	A3.3	0	0	0	4	0	0	4(10.8%)

principle screw back-out in 5 patients and screw cut out anterosuperiorly (or penetration into hip joint) in 3 patients, 1 of which had a reverse Z effect. None of the failures had hardware breakage. Two failures underwent revision surgery (1 hemireplacement & 1 re-osteosynthesis with ORIF + DCS), two patients are completely bed-bound and 4 patients with failed fixation are mobile but walk with a walker and painful limp. Among the failures, two patients had an average score of 5.5, four patients had score of 6 and two had score of 6.5. The fixation failure rates were 100% with score 5.5, 100% with score 6 and 66% with score 6.5. No fixations failed when the score was 7 in 12 patients, 7.5 in 9 patients and when it was 8 in 7 patients.

Scores of all the three observers were statistically significant (Table 4). The stability score had a moderately strong correlation with the fixation failure rate (r = 0.71, spearman's correlation, p = <0.001, Table 5). There was no significant difference of the stability score at 6 different fixation device types (p = 0.419, Table 3). Failure rate was also not different among the fixation types (p = 0.233). Inter- and intra observer reliability were calculated with an Interclass correlation coefficient (ICC) which were 0.75 and 0.89 respectively. There was 1 case of intra operative iatrogenic shaft of femur fracture treated with stainless steel wire encirclage with insignificant impact on patient mobilisation. There was no case of surgical site infection or avascular necrosis of head of femur. The inference we got from the study was as follows. Compared to an ideal fixation with score of 10, best possible fixation can be expected with a score between 8.5 to 9.5. Results were good with the score of 7.5 and above, fair with 6.5 and above and poor when the score was below 6.5 (Table 6). The minimum acceptable score is 6.5 in case of extra-medullary devices and 7 in case of intra-medullary devices.

Table 3: Association between failure rate and diagnosis, AO classification and fixation type

Variable	Category	Fixation Failure		Total	Chi-Square, P-value*
		No	Yes		
Sex[a]	Male	14 (48.3%)	5 (62.5%)	19 (51.4%)	0.508, 0.693
	Female	15 (51.7%)	3 (37.5%)	18 (48.6%)	
Diagnosis & side[a]	IT Fracture LT	15 (51.7%)	5 (62.5%)	20 (54.1%)	0.293, 0.701
	IT Fracture RT	14 (48.3%)	3 (37.5%)	17 (45.9%)	
AO classification type	A1	10 (34.5%)	2 (25.0%)	12 (32.4%)	8.736, 0.013
	A2	17 (58.6%)	2 (25.0%)	19 (51.4%)	
	A3	2 (6.9%)	4 (50.0%)	6 (16.2%)	
Fixation type	PFN long	6 (20.7%)	4 (50.0%)	10 (27.0%)	4.971, 0.419
	PFN short	16 (55.2%)	2 (25.0%)	18 (48.6%)	
	PFN A2 short	2 (6.9%)	0 (0.0%)	2 (5.4%)	
	DHS	3 (10.3%)	1 (12.5%)	4 (10.8%)	
	DHS + DRS	1 (3.4%)	1 (12.5%)	2 (5.4%)	
	AFN/Gamma Nail	1 (3.4%)	0 (0.0%)	1 (2.7%)	

* Statistically Significant if P<0.05, [a] Fisher's Exact test

Table 4: Association between each observer's scores and failure rates

Post Op Score	Outcome	N	Mean	Std. Deviation	t-value	P-value*
Post op score observer 1	Success	29	7.23	0.68	3.444	<0.001
	Fail	8	5.25	0.55		
Post op score observer 2	Success	29	7.51	0.67	4.312	<0.001
	Fail	8	6.50	0.71		
Post op score observer 3	Success	29	7.00	0.58	4.565	<0.001
	Fail	8	6.18	0.27		
Avg post op score	Success	29	7.27	0.47	7.389	<0.001
	Fail	8	6.08	0.37		

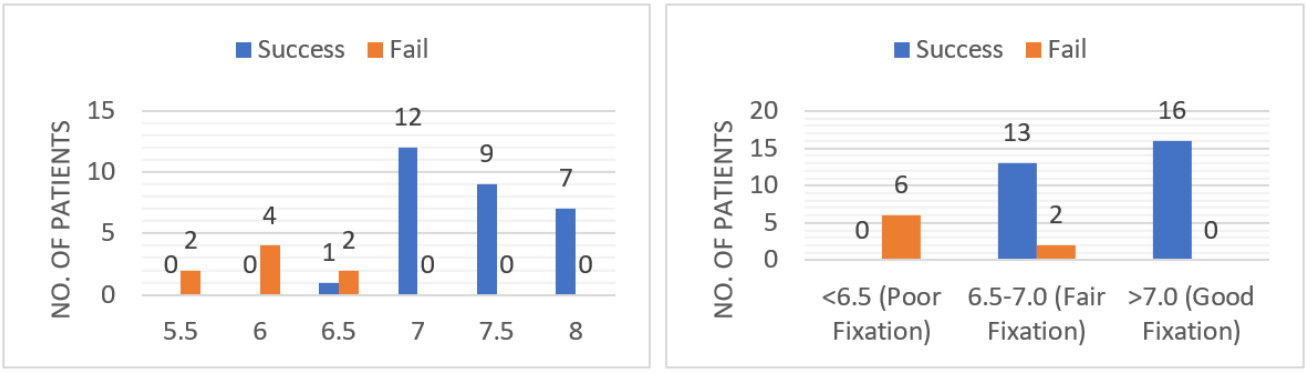
*Statistically significant if P<0.05

Table 5: Correlation between average scores and failure rates

Average Post op Scores	Failure		Total	Chi-Square, P-value
	No	Fail		
5.50	0 (0.0%)	2 (25.0%)	2 (5.4%)	33.066, 0.001
6.00	0(0.0%)	4(50%)	4(10.8%)	
6.50	1 (3.4%)	2 (25.0%)	3 (8.1%)	
7.00	12 (41.4%)	0 (0.0%)	12 (32.4%)	
7.50	9 (31.0%)	0 (0.0%)	9 (24.3%)	
8.00	7 (24.1%)	0 (0.0%)	7 (18.9%)	
Total	29 (100.0%)	8 (100.0%)	37 (100.0%)	

Table 6: Association between different score groups and failure rates

Score	Failure		Total	Chi-Square, P-value
	No	Fail		
<6.5	0 (0.0%)	6 (75.0%)	6 (16.2%)	26.772, <0.001
6.5-7.0	13 (44.8%)	2 (25.0%)	15 (40.5%)	
>=7.5	16 (55.2%)	0 (0.0%)	16 (43.2%)	
Total	29 (100.0%)	8 (100.0%)	37 (100.0%)	



Graph 1:

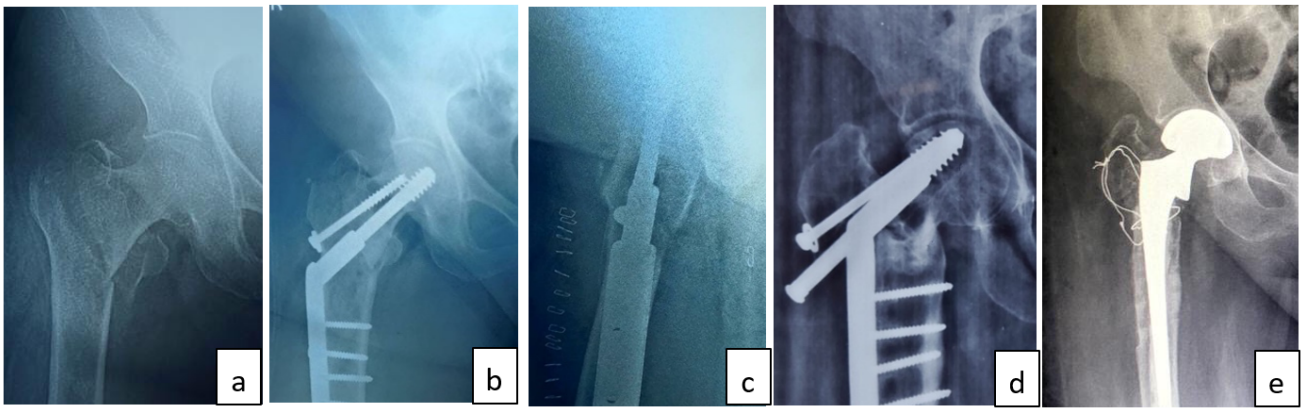


Fig. 2: Failed fixation case 1. Immediate post-operative radiographs of AO type 31A2.1 fracture show a total stability score of 6 (**b&c**). Fixation failed to achieve union with 6 months follow up X-ray showing varus collapse with screw back-out (**d**), subsequently revised to hemiarthroplasty

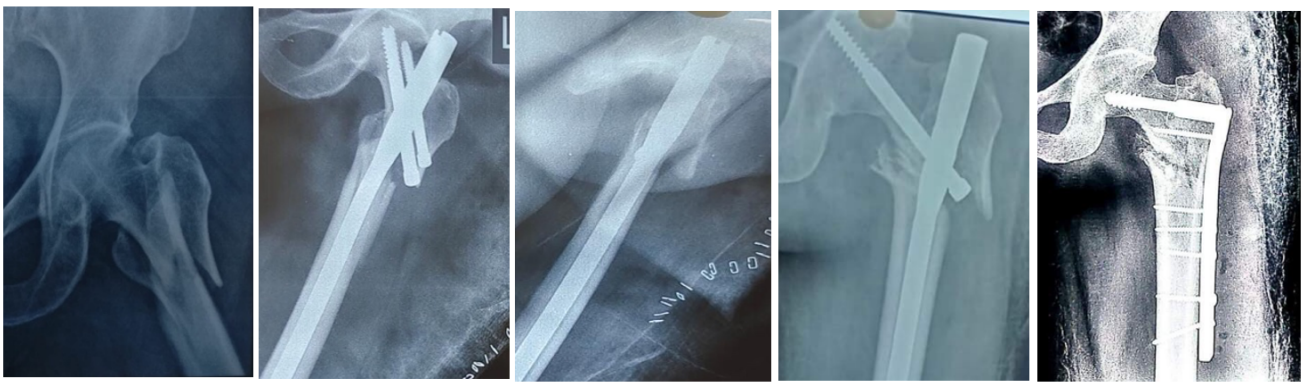


Fig. 3: Failed fixation case 2. AO type A3. 1 fracture fixed with long PFN, Immediate post opX-rays show a total stability score of 5. Weight bearing lead to reverse z effect with derotation screw back out and principle screw penetration into hip joint. Initially derotation screw was removed, followed by revision surgery with implant removal and ORIF + DCS

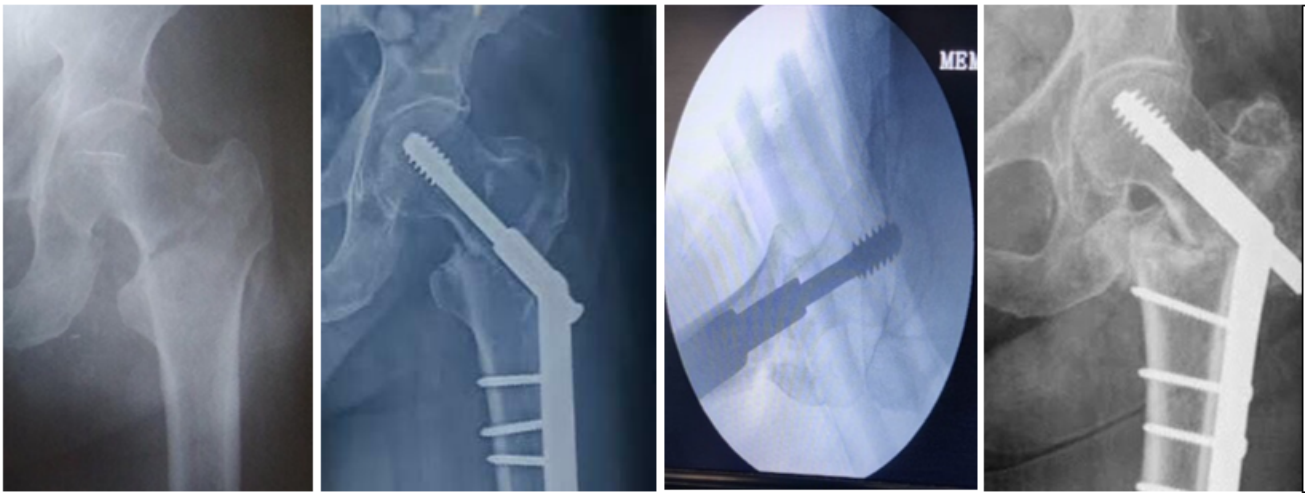


Fig. 4: Fixation failure case 3. Immediate post op X-rays after DHS fixation of AO type A1.2 fracture show stability score of 5.5. At 4 months follow up, patient has pain, limp, shortening of limb and palpable screw

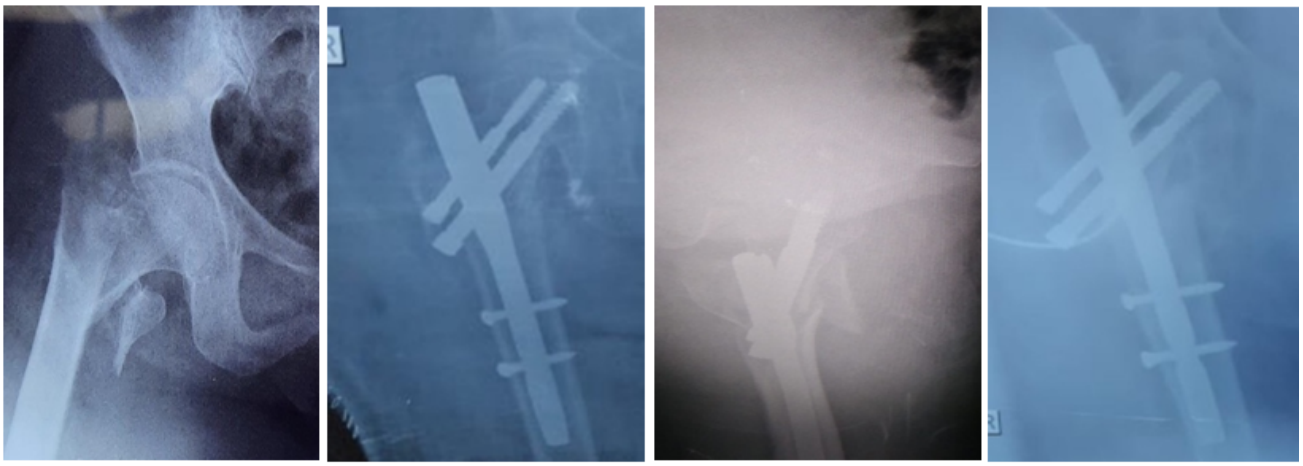


Fig. 5: Failed fixation case 4. AO type 31A2.2 type fracture treated with short PFN has postop score of 6. Fixation failed in 3 months with varus collapse and screw back-out. Patient is bedridden and not willing to undergo further surgery

3. Discussion

There is an increasing trend towards surgical stabilisation of intertrochanteric fractures with the improved understanding of fracture configuration and development of advanced fixation devices. As the surgeries increase, incidence of failures also increases. If revision surgery becomes necessary, it may portend a high possibility of mortality or at the very least a high rate of in-hospital morbidity and cost.[5] Ideal expectation of the surgery in IT fractures is full weight bearing mobilisation with or without assistance immediately after surgery. Unstable fractures pose difficulties in management either because of malreduction or unstable fixation leading to high chances of early implant failure before the fracture unites. Nonetheless a successful osteosynthesis is superior to hip replacement in view of faster surgery preserving the native hip, reduced blood loss, lesser wound complications, lesser chances of limb length discrepancies, reduced post operative morbidity and mortality rate.[13,14]

Studies have proven that, intra medullary nails perform better than extra-medullary implants in case of unstable fractures.[15,16] Some authors still prefer extra-medullary fixation in stable intertrochanteric fractures, given the reasons that intra-medullary devices are relatively newer with a learning curve, technically demanding and costlier than extra-medullary devices. Also, it takes more radiation exposure, more reoperation rates and more trained assistance.[17]

There are four major ways any osteosynthesis can fail. 1) The screw tip penetrating into the joint with concomitant impaction at fracture site. 2) screw back-out, loss of reduction with varus collapse. 3) screw cut

out anteriorly-superiorly through the head with associated varus angulation. 4) Hardware breakage, usually at the screw nail interface. To prevent fixation failure, many authors have proposed various guidelines and techniques of reduction and fixation. Principle requirements for faster recovery of patient with any fracture fixation are anatomical reduction and stable fixation. Various authors have described consideration of different parameters to decide about the stability of fixation. In a recent meta analysis done by Yamamoto et al., moderate certainty of evidence supported that intramedullary malreduction (negative cortical buttress) on the anteromedial cortex was associated with failed internal fixation.[18] Chang et al., in 2015 did a retrospective analysis of 127 patients of IT fracture treated with cephalomedullary nail and concluded that placement of proximal fragment slightly medial and anterior with respect to distal fragment leads to valgus alignment of fracture which is the ideal requirement for anatomical fracture union. It allows controlled and limited sliding of the proximal fragment to contact with femur shaft and achieve secondary stability, providing a good mechanical environment for fracture healing.[1] Baumgaertner et al. described that in DHS, TAD is useful intra operative indicator and that a TAD of <25mm had been shown to be generally predictive of a successful result.[4] Other studies have validated the TAD <25mm as a predictor of good outcomes even in case of intramedullary devices.[5–7] Pan S et al. in 2017 did a retrospective cohort study and postulated that, at the initiation of entry into proximal femur, a starting point slightly medial to the exact tip of the greater trochanter is recommended because reaming of proximal portion could lead to more lateral position of the intramedullary nail. Lateral position of the nail at the proximal portion can influence the formation of the varus angulation of the fracture site due to loss of buttress effect of the intramedullary nail and leads to the increased lateral lever arm of the hip joint.[8] Shivashankar et al., in 2021 gave 10 intra operative commandments for successful proximal femoral nailing which are purely dependent on surgeon's mindful and fracture specific skills. They also recommended that the patient should be mobilised as pain tolerated weight bearing with a walker as soon as possible after the fixation. It will boost patient's self-confidence, subsequently patient will cooperate for a suitable rehabilitation program.[2] But dilemma still exists among majority of the surgeons as far as weight bearing on the operated limb is concerned. Some prolong the immobilisation, some allow for partial weight bearing, toe touch or metatarsal head touch weight bearing and some full weight bearing. We felt that a scoring system including all these parameters is necessary for intra operative consideration to boost surgeon's confidence on his surgery so that he can decide on the appropriate rehabilitation program to avoid post op failure. On searching the web, we found that, Sung-Rak Lee et al. in 2012 had formulated a similar kind of scoring system in which they included contact of the posteromedial cortex, angulation and distraction at the fracture site.[19] But, these parameters are impractical in the day to day orthopaedic practice as measuring the amount of angulation and distraction is very difficult. They analysed only the intramedullary fixations. Also, the concept of cortical buttress has moved from posteromedial side to anteromedial side in the recent advancements in understanding the biomechanics of fracture healing in intertrochanteric fractures. Hence, we formulated a new scoring system and conducted this study.

4. Limitations of the Study

The current study has many limitations. A few among them are, this is a retrospective study with a smaller number of participants. We could not find out information about the intra operative difficulties faced, techniques to achieve reduction and progress of rehabilitation, such as the proper time to stand and walk independently without assistance. We did not include few rare primary and revision fixation devices like DCS, Proximal femoral locking plate, Angled blade plate etc., as there was no data. We could not get the immediate post-operative true see-through lateral view radiograph or C-arm images for few patients. We did not consider osteoporosis into account while assessing the fixation failures as we couldn't obtain BMD results of all the patients.

5. Conclusion

The newly proposed scoring system appears to be valid and promising intra operative guide for fixation of intertrochanteric fractures. It can be a potential useful tool for orthopaedic surgeons to predict accurately, the maintenance of the fracture fixation until union and to advise the appropriate rehabilitation program accordingly. Large scale multi centre prospective studies are needed in the future to support the current study or to further simplify this scoring system. We used only the plain radiograph or fluoroscopy for scoring. 3D CT based scores may be more accurate.

6. Source of Funding

None.

7. Conflicts of Interest

Nil.

8. Acknowledgement

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