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A comprehensive 3D CT based classification of intertrochanteric fracture

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ABSTRACT

Introduction: Despite advancements in surgical techniques complications like implant failure is very common after the fixation of intertrochanteric fractures. Classifying these complex fractures based on plain radiographs underestimates the complexity of these fractures which in turn leads to complications. We propose a comprehensive classification of the intertrochanteric fractures based on 3D Non Contrast Computed Tomography (3D NCCT) scan.
Material and methods: A total of 102 patients (51 males and 51 females) with intertrochanteric fractures were included in this study conducted over a time period of 22 months in a Tertiary care center in North India. NCCT proximal femur of the intertrochanteric fracture patients was done to formulate a new CT classification system and classify all fractures. Intra and inter-observer reliability was tested using kappa variance.
Results: New classification system was proposed which included 3 main and a total of 6 groups. All the fractures were classifiable into the new system. Kappa variance of the study showed a good intra and interobserver reliability (0.95 and 0.90) proving clinical agreement of the classification.
Conclusion: This new 3D-CT based classification has the advantages of being easy, comprehensible with high intra and inter-observer reliability. This 3DCT based classification can prove to be useful to detect occult intertrochanteric fractures undetectable in plain radiographs as well as choosing the optimum treatment plan.

1. Introduction

Intertrochanteric fractures are commonly operated fractures around the hip with a significant postoperative complication rate despite advances in the fixation methods used for the treatment of intertrochanteric fractures.[1] The problem probably lies in the misconception of stability and poor identification of the fracture morphology by plain radiographs.[2] Understanding the role of a posteromedial column, lateral column and identifying the unstable fractures can improve the fixation techniques and postoperative outcomes. Various available radiographically based classifications like Evan's, Jensen, Boyd and griffin, Arbeitsgemeinschaft Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification divides the fractures based on plain radiographs.[3-5] However, they all underestimate the role of the lateral and posteromedial columns on the stability of the fracture. X-rays do not reveal the status of the calcar femoral and amount of lateral column comminution and often lead to disasters both intra and postoperatively. There is ambiguity about stability in AO/OTA type A2 fractures as the subgroup classification does not take into account the status of the lateral wall and thus fails in defining the stability.[6] There are very high chances of failure in cases of fixation with any available implant in highly comminuted posteromedial as well as the lateral wall. There are a few uncommon patterns that are not classifiable according to any of the above classifications and hence posing a problem for fixation as well as rehabilitation.[7]

Proximal femur biomechanics is a complex concept that should be considered in all planes as it differs during standing, sitting, and squatting with all the activities leading to stress distribution on different areas.[8]

Computed Tomography considers all these lacking areas and provides a better understanding of the fracture pattern and status of both columns. Posteromedial column and lateral column are

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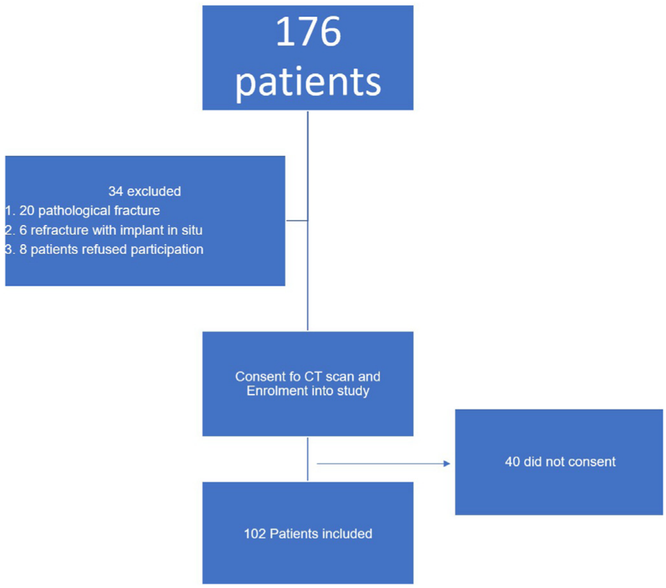

Fig. 1. Flow chart showing enrolment of patients.

better understood and their absolute comminution is delineated instead of using pseudo parameters. The current study aimed to propose a proper NCCT classification system and to check its reliability using various statistical parameters.

2. Patients and method

In this prospective, observational study, conducted in a tertiary care institute of north India over a period of 2 years from April 2018 to April 2020, a total of 176 skeletally mature patients with x-ray proven intertrochanteric fractures presented to the emergency department out of which 102 were enrolled (Fig. 1). Gender distribution of the enrolled patients was equal with 51 males and 51 females and mean age of 63.81 years with a standard deviation of 17.81 (range 21–98 years). A safe dose of NCCT proximal femur was calculated and clearance from the institutional ethics committee was obtained before the study. Informed and written consent was taken from all the patients before enrolment with a dose of NCCT foretold.

The new NCCT classification is formulated by 2 Orthopedic surgeons (RBK, SS) on the three column theory as described in Table 1. In the current study, fractures were broadly divided into 3 main groups and a total of 6 subgroups (Figs. 2–8). Each group has been classified according to the increasing instability and complexity of the fracture. New NCCT classification divides the proximal femoral region into 3 columns. They are defined as Posteromedial, Lateral and anteromedial columns.[9–12] The greater trochanter and lesser trochanters are traction epiphysis and serve largely as attachment sites for hip muscles. The columns flare up from the dense cortical bone of the femoral diaphysis and then narrow into the neck superomedially resulting in a sudden transition into a smaller cross-sectional area. The posteromedial column ends higher than the lateral column which in turn ends higher than the antero-medial column due to the eccentric anterior overhang of the greater trochanter.[9] Most simple patterns of intertrochanteric fractures involve the posteromedial column with the fracture exiting above the lateral and the antero-medial column.[10] The lesser trochanter is a prominence in the posteromedial column and fractures of the lesser trochanters beyond the base affect the stability of the internal trabecular architecture of the proximal femur and cause persistent instability of the posteromedial column even after accurate reduction of the column.

Based on the involvement of the number of columns the fractures were classified into three main groups as listed in Table 2. A column is considered to be stable if there is a single fracture line within a column.

A column is considered unstable if there are two or more fracture lines in a column creating an intermediate fragment. Based on the presence of these criteria the three groups were further subclassified into types A and B.

Two Orthopaedic surgeons and One Radiologist were briefed about the new classification who were not involved in the formulation of classification, the pictures of the three columns with details of each subtype were provided with CT DICOM images of all the 102 fractures and each fracture was subsequently classified. First, classification according to the new CT Classification was done by observer 1 (BS -an experienced Consultant Orthopaedic surgeon) which was recorded as session 1 and after three months again classification on the same images was done by observer 1 which was recorded as session 2. At the same time observer 2(SP – Senior Resident Orthopedics) and observer 3 (PS- Experienced Consultant radiology) classified fractures according to the CT-based new system. Session 1 and 2 were utilized for calculation of intra-

Table 1
The anatomical extent of the Postero-medial (PM),Lateral(L) and the Antero-medial (AM) columns.

Column	Medial extent	Lateral extent	Superior extent	Inferior extent
Postero-medial (PM)	Attachments of the hip capsule to the intertrochanteric crest superiorly and inferiorly to the midline below the lesser trochanter.	Line drawn vertically from posterior edge of vastus lateralis ridge	Horizontal line from the postero-inferior end of vastus lateralis ridge to intertrochanteric crest below the flare of the greater trochanter	Line drawn horizontally 2 cm below the lower extent of lesser trochanter
Lateral(L)	Line drawn vertically from anterior edge of vastus lateralis ridge	Line drawn vertically from posterior-inferior edge of vastus lateralis ridge	Superiorly curved Vastus lateralis ridge	Line drawn horizontally from 2 cm below the lower extent of lesser trochanter
Anteromedial (AM)	Inferior most point of attachment of the hip capsule to the intertrochanteric line superiorly to the mid-point of the medial surface below the lesser trochanter.	Line drawn vertically from anterior edge of vastus lateralis ridge	Line drawn horizontally from anterior edge of vastus lateralis ridge upto intertrochanteric line inferior-most point below the flare of the greater trochanter.	Line drawn horizontally from 2 cm below tip of lesser trochanter

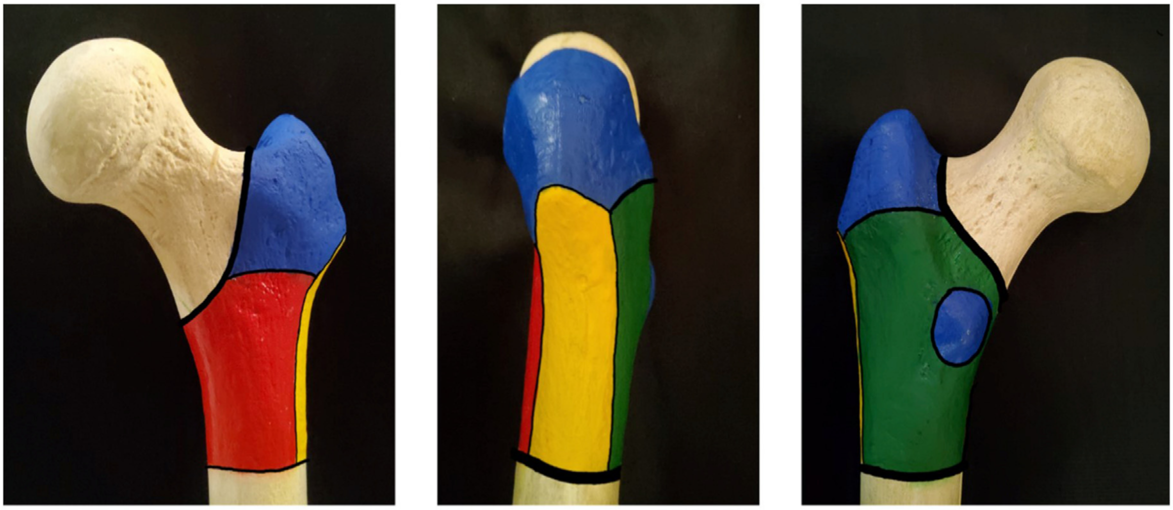

Fig. 2. Proximal Femur columns – Antero –medial column (Red area), Lateral Column (Yellow area) and Postero –medial column (Green area).The greater trochanter and lesser trochanter are in blue.

observer reliability and classified data of session 2 of observer 1 with observers 2 and 3 were utilized to calculate inter-observer reliability.

3. Results

The frequency distribution of the intertrochanteric fractures is shown in Fig. 9. The average age of patients included in the study was 63.81 years.

The analysis is shown in Table 3, Cohen's kappa shows intra-observer agreement was 95.1% which was done 1 month apart by observer 1. Observer 1 and 2 had an agreement of 93.1%, 90.7% between observer 1 and 3, 90.1% between observer 2 and 3. Fleiss's kappa shows near-perfect agreement between all 3 observers. The overall agreement between all 3 raters was 0.908 with an agreement of 90.4%.

On CT scan images, occult fractures of the lateral wall were found in 36.7% which were not discernible on plain radiographs

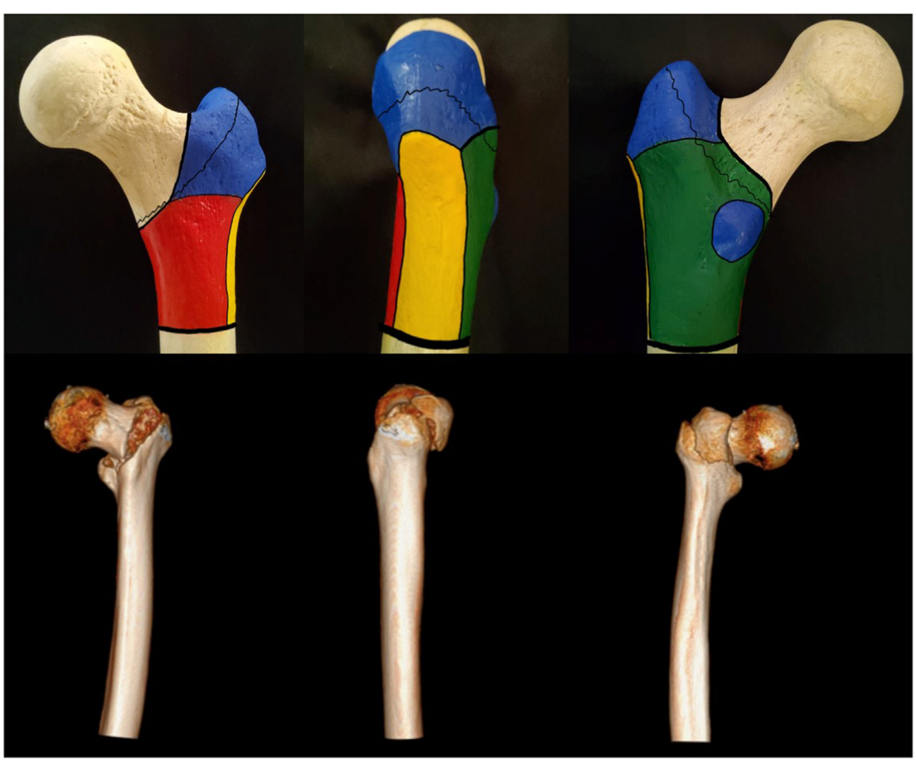

Fig. 3. Type IA Posteromedial Column, stable.

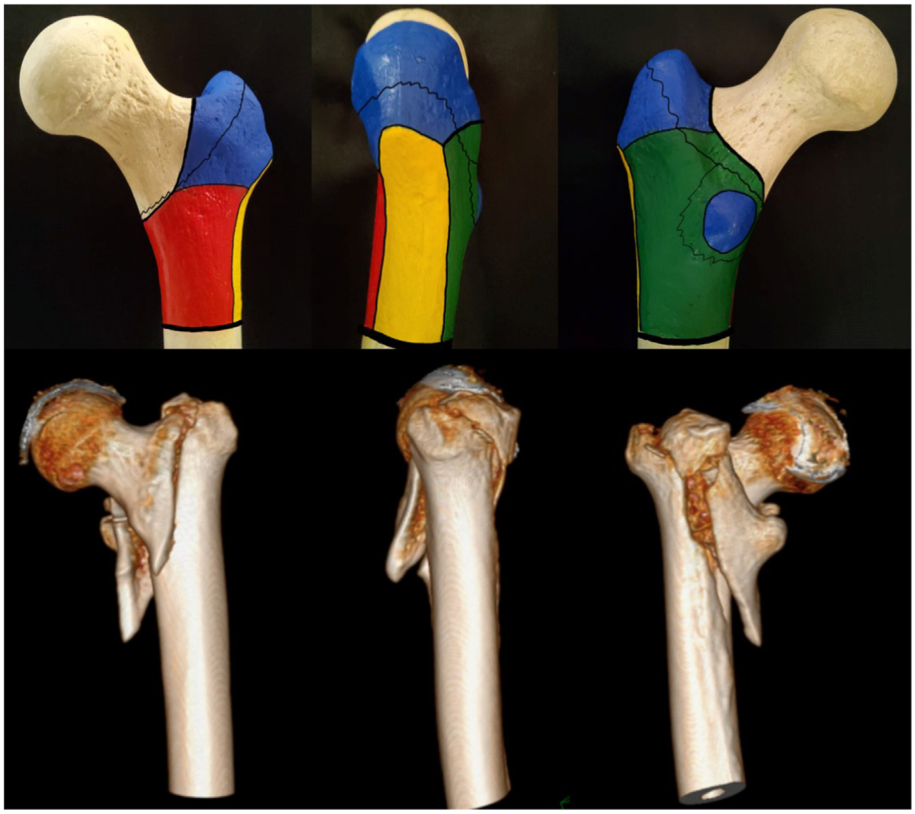

Fig. 4. Type IB Posteromedial column, Unstable.

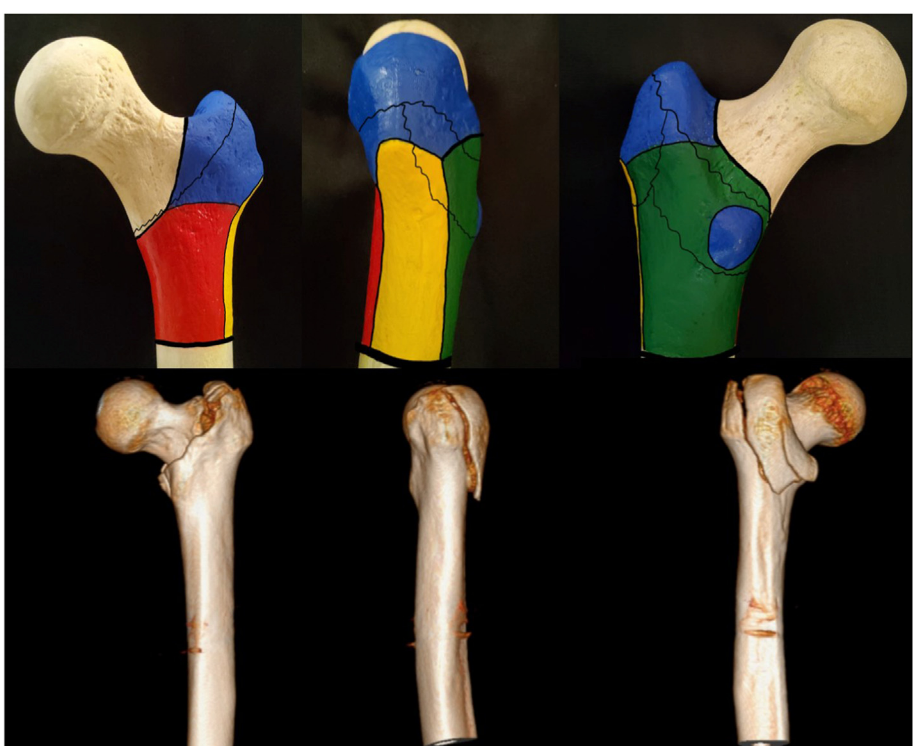

Fig. 5. Type IIA PM + L/AM column with both Stable.

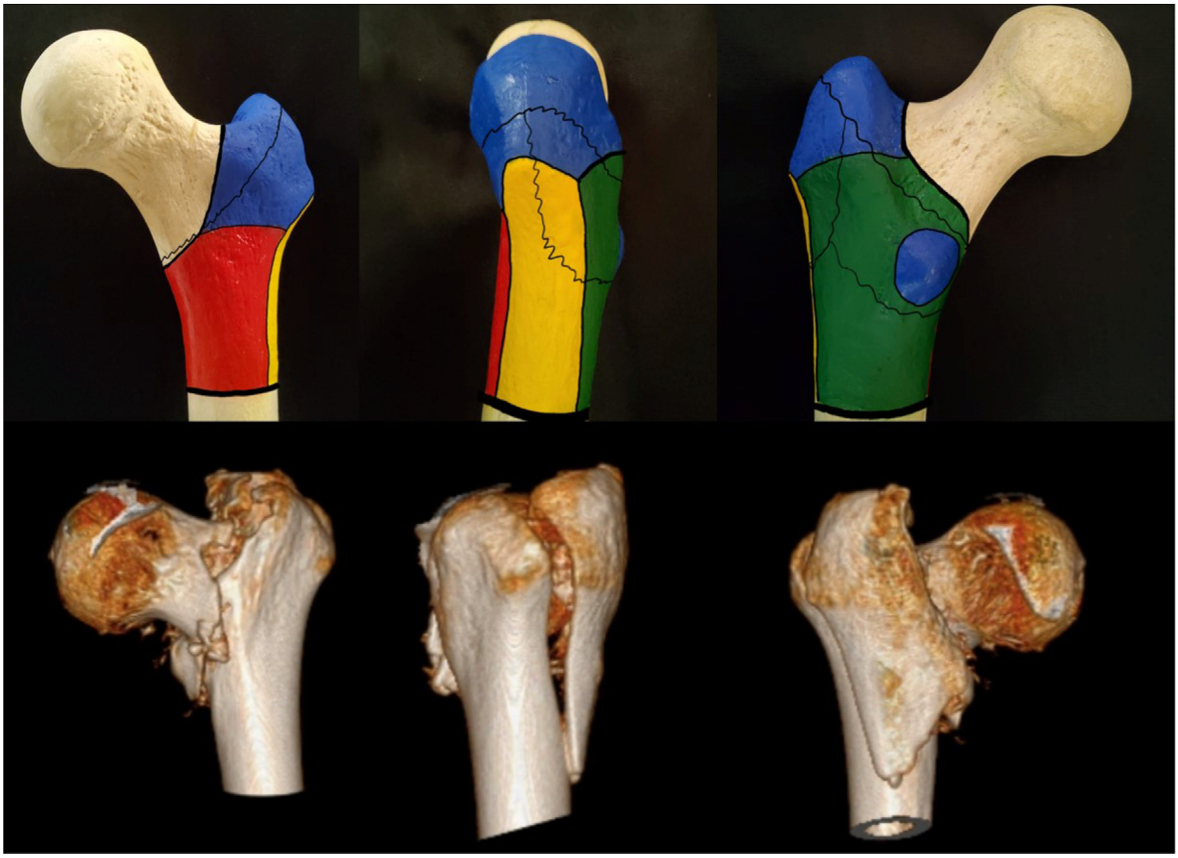

Fig. 6. Type IIB PM + L/AM column with one unstable.

and uncommon variants were found in 11.7% out of the 102 patients.

4. Discussion

4.1. Intertrochanteric fractures are classified into many systems based on the plain radiographic appearance. The purpose of an Ideal classification is to fulfill 3 components of patient management in the intertrochanteric fractures that include

1. Prognosis of the injury
2. Preoperative planning with good user reproducibility
3. Postoperative rehabilitation

We devised a new classification system after carefully studying the NCCT scans in the current study.

Through existing literature, our understanding of intertrochanteric fractures has come a long way since Evan and Boyd Griffin tried to classify them in 1949. Evan was the first to evaluate the importance of the posteromedial cortex and its implication in intertrochanteric fractures.[3] With the advances in technology and understanding of the proximal femur stress distribution patterns, Zhang et al. demonstrated the importance of calcar femoral in stress distribution, as it redistributes the various stresses from posterior and medial to the lateral and anterior wall.[13] Aprato et al. showed significant functional loss between fixation of the lesser trochanter with those left alone thereby concluding the importance of lesser trochanter fixation in intertrochanteric fractures.[14] Kai-Feng Ye et al. also evaluated the importance of posteromedial column in unstable intertrochanteric fractures and concluded that loss of posteromedial support was an independent factor in the loss of fracture fixation.[15]

Sharma et al. differ from the previous studies as they calculated the fragmentation of posteromedial fragment and its implications with the stability of fracture on 3D CT. The posteromedial fragment was not found to predict stability rather lateral wall fracture was found to be the main predictor of the pre and perioperative stability of intertrochanteric fractures. Multiple studies agreed to the importance of lateral wall integrity as the main predictor of implant failure and emphasized preoperative evaluation of lateral wall and due consideration is required for planning and classifying the fractures. [12,16-19]

Babhulkar et al. modified the existing AO/ASIF classification and summarised that lateral and posterior wall fractures should be identified preoperatively and should not rely on Xray findings rather CT scan should be done for careful planning. However, a key factor leading to high morbidity and mortality in these patients was the choice of implant and associated complications.[20] Tan et al. described the uncommon variant of intertrochanteric fracture which is not described in any of the classification systems. They found that rather than the posteromedial column it was the lateral wall fracture and loss of superolateral cortex that led to failure. The conclusion from the study was drawn that NCCT is necessary for preoperative planning rather than relying on plain radiographs.[7]

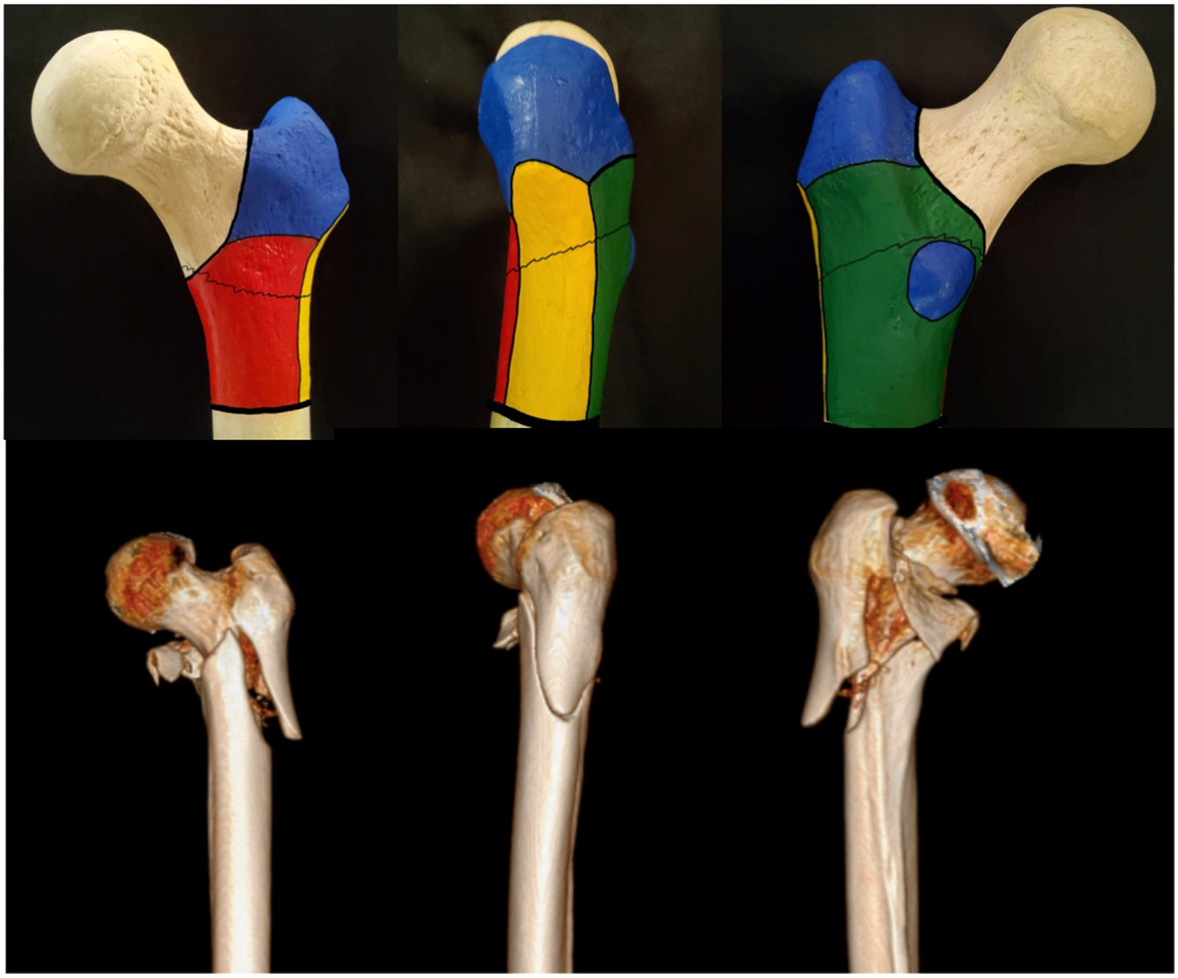

Fig. 7. Type IIIA All 3 columns with 2 columns stable.

Akhil et al. listed factors imparting instability in intertrochanteric fractures and found that lateral wall and greater trochanter fractures should give strong consideration preoperatively for a treatment plan.[21] Over the years many classification systems had been described but there had been no consensus regarding the application of any one of them.[22] AO/OTA is the widely used classification system by the orthopaedic fraternity for intertrochanteric fractures.

AO/OTA classification divides the fracture into three main groups on basis of appearance on X-rays and the current study classifies them into 3 main groups with increasing instability on basis of NCCT and 3D reconstruction. Multiple studies proved the poor reproducibility of fracture patterns by X-rays and recommended the use of CT scan in preoperative decision-making and planning.[23,24] Li et al. mapped the various fracture lines in the intertrochanteric fractures in their study and found that the medial column and lateral wall were frequently involved and were not given due considerations in the existing classifications and rather require a new system based on this information guiding the surgeons for a treatment plan.[10] Hence, lateral wall reconstruction was important and should be given due consideration in intertrochanteric fractures.

Reliability of various classification[25–29] along with the current study shows that all classification has poor to moderate observer agreement in contrast to the current study as shown in Table 4 which show a good agreement compared to previous ones.

Comparing the previous classifications based on plain radiograph with studies classifying on basis of CT scan, Kappa agreement is better in the CT classifications.

K. Futamura et al. devised a new classification system for intertrochanteric fractures based on the fracture line course and the attachment of the iliofemoral ligament on 3D CT images. A total of 74 patients were included in the study. 3DCT images were taken for every patient and fractures were classified into 3 patterns based on the relation between fracture line and iliofemoral ligament attachment. These were the lateral wall, transverse, and reverse oblique. They also identified a few atypical patterns not described routinely. Also, the mean kappa value was 0.76 and 0.77 for inter and intraobserver variance respectively.[30]

Shoda et al. also submitted a 3D CT-based new classification system based on the number of fragments. 239 patients with fractures of the intertrochanteric region were enrolled in the study. They interpreted from their study that on plain radiographs, evaluation of the various fracture pattern of the greater trochanter was difficult which included large oblique fragments including the lesser trochanter. However, it was easier to classify the fracture pattern based on 3D CT images as they clarified all the fracture lines appropriately. But observer agreement of the classification was not verified in the study.[31]

Comparing the current study with existing CT classifications,

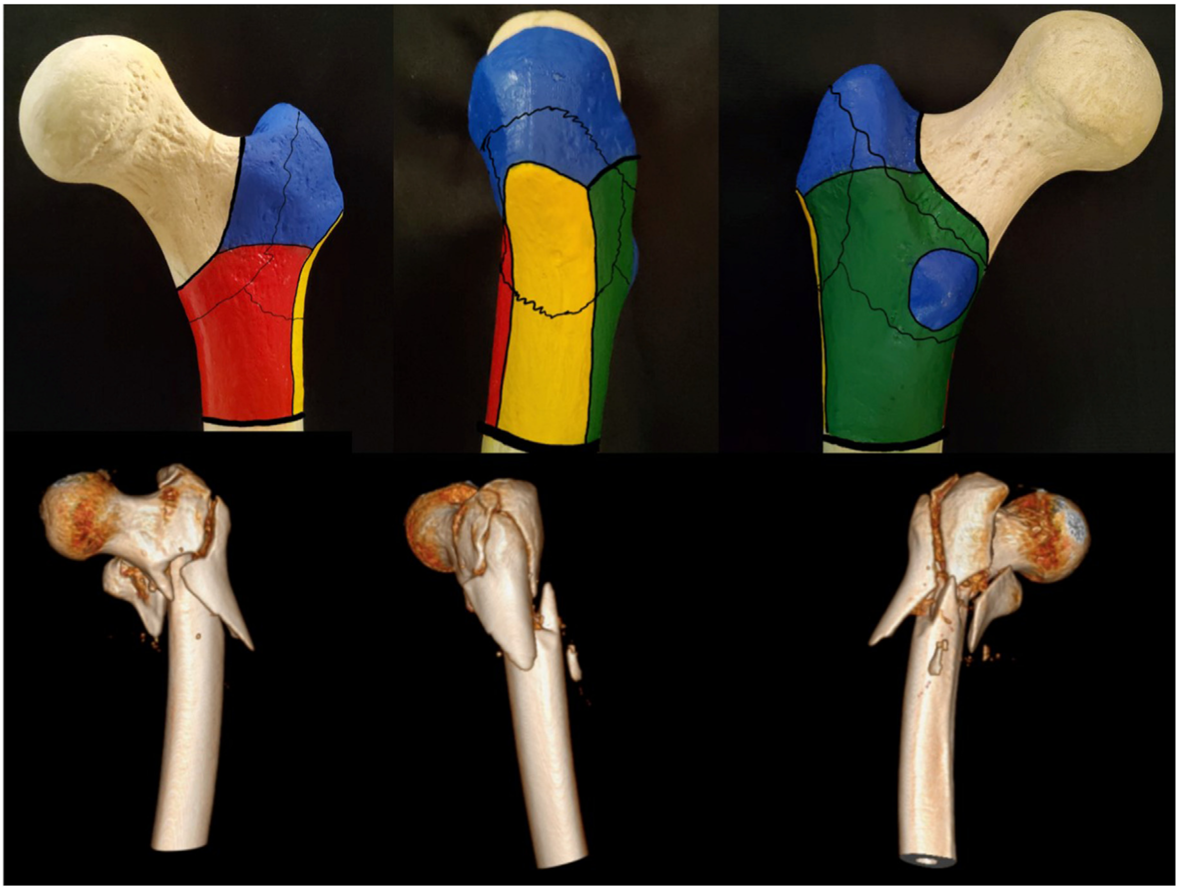

Fig. 8. Type IIIB All 3 columns with one column stable or none stable.

Table 2
Kalia and Singh's CT Classification of Intertrochanteric fractures.

Type	Column	Subtype	Stability
I	One column injury- Postero-medial (PM)	IA	Stable
		IB	Unstable
II	Two column injury-Postero-medial (PM) column with either lateral(L) or antero-medial (AM) column involved	IIA	Both columns stable
		IIB	Any one column unstable
III	Three column injury (PM + L + AM)	IIIA	Two columns stable
		IIIB	Two or more columns unstable

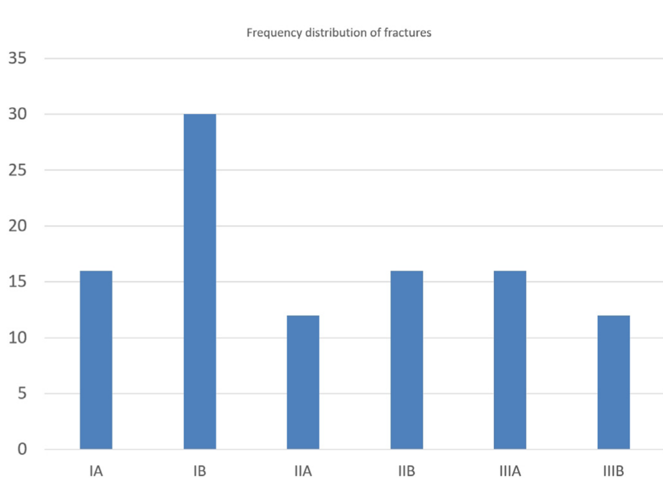

Fig. 9. Frequency distribution of fractures.

both the existing studies did not explain the role of lateral column integrity and did not classify the uncommon patterns into new types but proved the role of NCCT in intertrochanteric fractures. AO has also added CT to one of the modalities for classifying the intertrochanteric fractures.[32]

The findings of this study need to be validated by other studies for the generalisability of results and probably the use of NCCT classification for choosing an appropriate treatment plan. Implant choice should be made according to the type of fracture with various factors being taken into account like osteoporosis, amount of lateral wall comminution. Only using an intramedullary nail with no addressing of posteromedial or lateral wall fragments has often resulted in poorer outcomes.[2,7,33,34] We have postulated a basic framework that can be followed for implant choice in various types of fractures (Table 5). It further needs a good amount of studies to find a better implant choice for complex fractures. Further studies are required to validate the CT classification proposed and its clinical as well as biomechanical relevance. The limitation however is the availability of the CT machine in all the hospitals as well as 3D reconstruction of the fracture.

Table 3
Intra-observer reliability of the Kalia and Singh's CT classification.

Variable	Intra observer	Observer 1 and 2	Observer 1 and 3	Observer 2 and 3	All 3 observers
Cohen's unweighted	0.957	0.937	0.923	0.912	–
Cohen's weighted	0.988	0.991	0.974	0.973	–
Fleiss's kappa	0.916	0.922	0.911	0.902	0.908
% of agreement	95.1%	93.1%	90.7%	90.1%	90.4%

Table 4
Interobserver reliability of various classification system.

Study	Inter-observer reliability (kappa variance)		
	AO/ASIF classification (only main groups)	AO/ASIF subclass included	Other classifications
Wen jie jin	0.79	0.32	Evan's- 0.22 Kyle- 0.32 Boyd and griffin- 0.29
Pervez	0.63	0.33	Jensen – 0.34
Schipper	0.78	0.48	–
D van Embden	0.72	0.45	Jensen- 0.40
Tom J crijns	0.86	0.42	–
E Anderson		–	Evan's- 0.38–0.68
Gehrchen		–	Evan's- 0.41–0.68
Futamura			NCCT classification- 0.76
Current Study (Kalia and Singh's Classification		–	NCCT classification- 0.90–0.95

Table 5
Final Postulate for fixation according to type of fracture.

Type	Proposed Treatment modality
Ia	Extra medullary fixation
Ib	Extra medullary/Intra medullary fixation
IIa	Intra medullary fixation
IIb	Intra medullary fixation with/without lateral Column reconstruction
IIIa	Intra medullary fixation with lateral Column reconstruction + PM fragment fixation
IIIb	Intra medullary fixation with lateral Column reconstruction + PM fragment fixation

5. Conclusion

Classification of Intertrochanteric fractures has evolved. However, guiding the treatment of these fractures is still challenging. Plain radiographs and classification based on them haven't proved much beneficial and have ambiguity regarding management. 3DCT classification provides a comprehensive analysis of the fracture pattern. New Kalia and Singh's classification is comprehensive, includes all types of fractures, is reproducible, and is easy to use as well as document. The external validity of the classification with use for treatment needs to be further studied.

Ethical approval

Obtained.

Consent to participate

Obtained from every patient.

Consent to publish

All authors agree for publication.

Authors contributions

BS, SP helped in classifying the fractures. SSA and RBK formulated the plan for classification. SS collected the data and main writing part of the article.

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Availability of data and material

Available if required.

Declaration of competing interest

NONE.

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