

Biplane Fractures of the Distal Femur: A Proposed Computed Tomography-Based Classification and Surgical Management

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Learning Point of the Article:

New classification system helps to understand the fracture configuration and implant selection using 3D imaging.

Abstract

Introduction: Management of periarticular fractures requires a careful understanding of fracture characteristics and proper pre-operative planning. We suggest a new computerized tomography (CT) based classification system, which assists in planning surgical approaches and in implant selection, and provides an addition to the metaphyseal comminution along with the articular type.

Materials and Methods: 50 patients with biplanar distal articular fractures were included in our study and were classified using the CT-based classification. The CT images and intra-operative photographs were reviewed by five independent orthopedic surgeons and one radiologist to assess the reliability of the classification system. Postoperatively, patients were followed up at regular intervals, and range of motion and the Knee Society Score were assessed at 6 months.

Discussion: AO Muller's classification gives a good idea of metaphyseal and intra-articular involvement, which is followed worldwide for plan of management and fixation. This is based on 2D images. The classification described here is based on CT imaging, in which the 3D configuration has subtypes based on fracture fragments involving both intra-articular and extra-articular, which helps in understanding the fracture configuration in 3D and also helps in fixation of the fracture.

Results: According to our proposed CT-based classification, distal femur fractures are classified as uniplanar (A and B) and biplanar types (C, D, E, and F). Among the biplanar fractures, the severity of articular comminution increases from type C to type F. We found that among the biplanar fractures, Type D (three-part fracture) was the most common fracture type. We found that Type C fractures had the best outcome, whereas type F had the worst functional results.

Conclusion: This CT-based classification system can assess the severity of the articular comminution, decide the surgical approach and implant selection, and grade the prognosis.

Keywords: Distal femur fractures, three-part, 4-part fractures, CT scan, metaphyseal comminution, biplanar fractures.

Introduction

Distal femur fractures represent <1% of all fractures [1,2]. These fractures are frequently comminuted and have intra-articular

involvement [3]. Principles of management of distal articular femur fractures are similar to those of any other articular fracture, i.e., to achieve anatomical reduction of the fracture fragments

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while providing rigid fixation to allow early functional mobilization [3]. Management of periarticular fractures requires a careful understanding of fracture characteristics and proper pre-operative planning [4]. Management of combined distal femoral intercondylar fractures along with coronal plane fractures has received very little attention in the past [5]. Proper pre-operative imaging of these injuries may assist in the planning of surgical approaches and the selection of implants [6].

The present AO-OTA classification is a radiograph-based classification system. The presence of multiple fragments and the orientation of the fragments are now simplified with the use of computed tomography [6]. The presence of combined sagittal and coronal plane fractures of either or both condyles necessitates that it be classified as AO-OTA type 33 C3 or multifragmentary articular type [5]. A single category 33 C3 does not provide adequate information about the degree of articular comminution and cannot predict the functional outcome. Similarly, B3 represents all types of coronal plane or Hoffa's fractures. However, a combined unicondylar sagittal fracture associated with a coronal plane fracture of the same condyle cannot be categorized according to the AO-OTA classification. Thus, we feel that there is a necessity for a new CT-based classification system for distal articular femur fractures, which can predict the severity, assist in the planning of surgical approaches, aid in implant selection, and suggest the functional outcome. The proposed CT-based classification is described (See Table 1) and its implications for the surgical management of biplanar articular fractures have been discussed in this article (Table 2 and Fig. 1).

In this study, we have included only the biplanar distal femoral articular fractures and evaluated the fixation techniques and functional outcomes in these patients. The degree of metaphyseal comminution should be considered separately, as the restoration of the articular surface is essential, irrespective of the degree of metaphyseal comminution. Accordingly, we have graded the degree of metaphyseal comminution separately.

Materials and Methods

This study was conducted at the Department of Orthopedics between May 2018 and June 2023. A total of 50 patients with distal articular biplanar femur fractures were included in our study. Pre-operative CT evaluation was done in all patients. Demographic details and the mechanism of injury were documented for all the patients. Surgical planning, including the approach and implant selection, was made based upon the proposed classification (Fig. 1). The suggested classification is as follows. Type A and B are uniplanar fractures but, for the sake of completeness, have been included in the picture. Types C, D,

and E are biplanar fractures with increasing degree of comminution. Type C represents a 2-part fracture with combined coronal and sagittal fractures in one condyle. C-L and

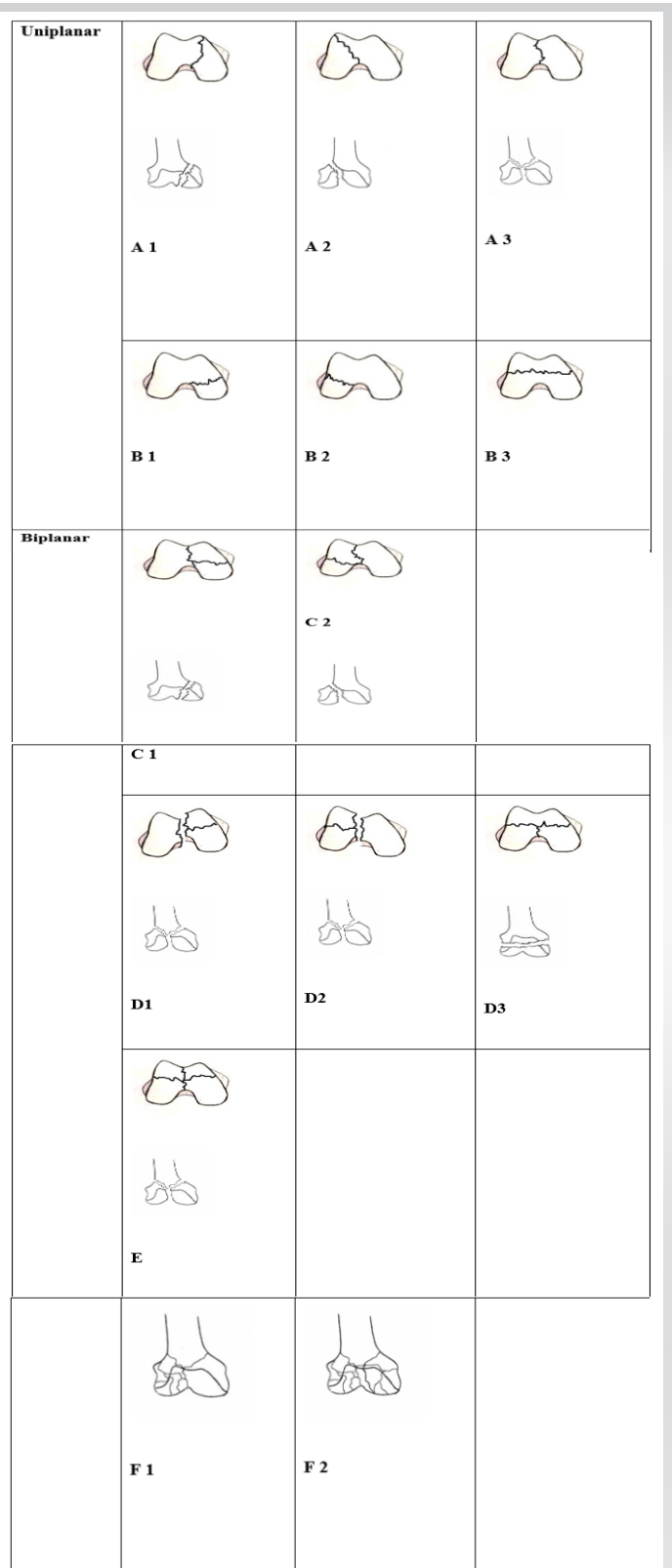


Figure 1: Pictorial description of the proposed computed tomography-based classification.

C-M have been used to represent the medial and lateral condyles. In type C fractures, there is metaphyseal continuity in the other condyle. Type D represents a 3-part fracture with combined sagittal and coronal fractures in one condyle, whereas the other condyle has a uniplanar fracture. Terminologies D-L and D-M are used to suggest the biplanar involvement of the lateral or medial condyle, whereas D and C suggest that there is a distal femur fracture associated with a bicondylar Hoffa's fracture. Type E represents a 4-part fracture, wherein there is a combined coronal and sagittal fracture in both condyles. Type F suggests a comminuted fracture.

The metaphyseal comminution was graded as M0 if there was no comminution. M1 and M2 represent moderate and severe comminution, respectively, and M3 suggests comminution with bone loss.

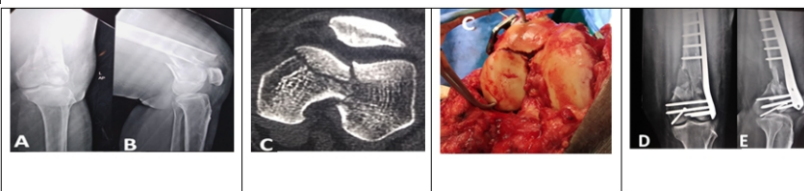
Intraoperative photographs were also taken to confirm the CT findings. Postoperatively, patients were reviewed once every 15 days, and radiographs were repeated every 30 days. All the patients were followed up regularly for 6 months. Fracture healing time, post-operative complications, and Knee Society Scores were recorded in all patients.

Interobserver and intraobserver reliability for the classification was also assessed. To assess the interobserver reliability, five orthopedic consultants with more than 6 years of clinical experience and one radiologist were contacted. Each consultant received five randomly selected radiographs, CT images, and intra-operative photographs of different patients and was asked to classify them according to the above classification. The same exercise was repeated after an interval of 4 weeks to assess the intraobserver reliability.

Type C: 2-part fracture



Type D: 3-part fracture



Type E: 4-part fracture



Type F: Comminuted intra-articular fracture

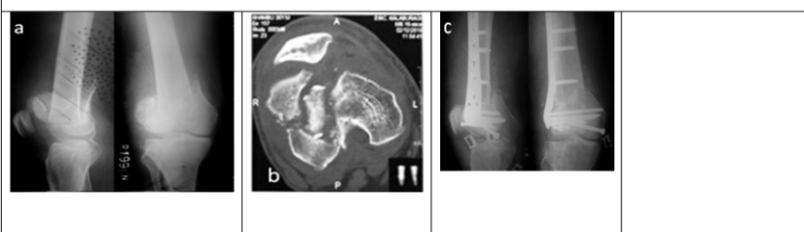


Figure 2: Radiograph, computed tomography, and clinical pictures of the proposed classification. Post-operative pictures after fixation of the fracture. (a-e) Type C: 2-part fracture, (a-e) Type D: 3-part fracture, (a-d) Type E: 4-part fracture, (a-c) Type F: Comminuted intra-articular fracture.

General principles

1. Approach: We prefer an anterior approach for biplane articular fractures. The medial or lateral parapatellar approach is decided based upon the coronal fracture.

2. Reduction: An accurate anatomical articular reduction is essential before proceeding to metaphyseal fixation. Reduction of coronal fracture fragments is achieved first before the sagittal fracture fixation.

3. Articular fixation: Headless compression screws and countersunk cancellous screws were used for coronal plane fractures. The sagittal fractures were fixed with one or two cancellous screws. This converts the multifragment articular fracture into one articular block, which can be fixed with the metaphyseal segment. In 2-part biplane fractures (Type C), only screw fixation is sufficient, with or without a buttress plate. In 3-part and 4-part biplane fractures, we need to identify the condyle that has no associated coronal plane fracture. This condyle was labeled as "the stable fragment." In such fractures, a locking plate should be applied between the stable fragment and the metaphysis. If both condyles have coronal fractures (Type E), then the decision for bicolumnar plate fixation should be taken intra-operatively, depending upon the stability of the fixation.

4. Metaphyseal fixation: In M1 cases, we fix the articular block and the metaphyseal fragments with a locking plate using the minimally invasive method. In M2 fractures, the plate is fixed in

Table 1: Describing the CT-based proposed classification system

Fracture	Type	Subtype	AO-OTA Equivalent
Uniplanar	A. Sagittal	1. Medial condyle	B1
		2. Lateral condyle	B2
		3. Intercondylar	C1
	B. Coronal	1. Medial Hoffa	B3.2
		2. Lateral Hoffa	B3.2
		3. Bicondylar Hoffa	B3.3
Biplanar	C. Two part	1. Medial	-
		2. Lateral	-
	D. Three part	1. Medial	C3
		2. Lateral	
		3. Central	
	E. Four part	4 parts in the distal femur	C3
	F. Multifragment	1. Unicondylar	C3
		2. Bicondylar	C3
CT: Computed tomography			

bridging mode. M3 cases are mostly associated with open wounds, and bone cement was used to fill the metaphyseal defect. The bone cement is later replaced by bone grafting using the Masquelet technique.

Results

Fifty patients with biplanar distal articular fractures were included in our study. Road traffic accidents with a head-on collision were the most common mode of injury. Eight patients had a compound wound. Four patients had other associated fractures. Anterior cruciate ligament and posterior cruciate ligament avulsions were present in three patients.

The mean age was 35 years. The male-to-female ratio in our study was 5:1. The most common fracture type was D, followed by C, E, and F, respectively. ROM in each group of fractures was recorded at every follow-up. Patients with C- and D-type fractures had a good range of motion of more than 100°. While the patients who suffered type E and type F fractures had an average range of motion of <80°. One patient who suffered from a type E fracture and had a grade IIIB compound injury developed wound infection, which subsided with secondary debridement and cement bead placement. Two patients who had M3-type metaphyseal fractures required secondary bone grafting after 6 weeks. One patient of with a type D3M3 had a 1.5 cm shortening, which was managed with a shoe raise. Two patients had a significant post-operative varus deformity, and one had a valgus deformity. One patient had non-union and was lost to follow-up. The clinical and radiological representative pictures are shown in Fig. 2.

The interobserver agreement was 87.5%, and the intraobserver agreement was 100%. The chance-corrected and weighted

kappa statistics for observer agreement, both for inter-observer and intra-observer variability, demonstrated satisfactory repeatability of the classification system.

Discussion

Various classification systems have been described in the literature [7,8]. The most commonly used classification system for distal femur fractures is the AO OTA classification [9]. In this classification, the distal femur fractures are broadly classified into type A, B, and C, corresponding to extra-articular, partially intra-articular, and fully intra-articular [9]. Each group is further subclassified into three types based on the pattern of the fracture and degree of comminution. Type B1 involves sagittal split of the Lateral condyle; B2 involves sagittal split of the medial condyle, and type B3 represents a coronal plane fracture known as a Hoffa's fracture. Type C is subclassified into C1 (simple articular, simple metaphyseal), C2 (simple articular, multifragmentary metaphyseal), and C3 (multifragmentary articular and metaphyseal).

Table 2: Patient demographic details and post-operative follow-up findings

Mean age	35 years
M: F ratio	05:01
Classification	Number of patients
Type C	24
Type D	18
Type E	5
Type F	3
Classification	Mean post-operative ROM
Type C	0–115°
Type D	0–102°
Type E	10–70°
Type F	10–50°
Complications	
Infection	1 patient (Type E)
Non-union	1
Delayed union	1 patient (Type D2)
Deformity	2 patients Varus >15°
	1 patient Valgus >15°
Shortening	1 patient type (D3 M3)

Table 3: Describing the fracture classification, approach, implant selection, and prognosis following fracture fixation

Classification	Description	Approach	Implant	Average Knee Society scores
CM	Two-part fracture with medial condyle coronal fracture	Medial parapatellar	Headless screws with or without a buttress plate	84
CL	Two-part fracture with medial condyle coronal fracture	Lateral parapatellar	Headless screws with or without a buttress plate	86
DM	Three-part articular fracture with coronal fracture involving the medial condyle	Medial parapatellar	Headless screw and standard distal femur LCP	78
DL	Three-part articular fracture with coronal fracture involving the lateral condyle	Lateral parapatellar	Headless screw and standard distal femur LCP and additional medial condyle plate	76
DC	Central articular fracture with bicondylar coronal fracture	Medial or lateral parapatellar	Headless screw and standard Distal femur LCP with or without medial condyle plate	74
E	Four-part articular fracture	Medial or lateral parapatellar	Headless screw and standard distal femur LCP	68
F	Comminuted unicondylar/bicondylar fracture	Medial or lateral parapatellar	Multiple screws and bridge plating	35
		Percutaneous pin fixation for external fixator	Knee spanning external fixator	22

CM: Medial condyle, CL: Lateral condyle, DM: biplanar involvement of medial condyle, DL: biplanar involvement of lateral condyle, DC: distal femur fracture associated with a bicondylar Hoffa fracture.

The above classification is simple, valid, and provides a good picture of the severity of the distal femur fractures. However, it is an X-ray-based classification. The inability of the AO system in classifying biplane fractures has been well explained by Nork et al. [5]. In their study, they found that associated coronal plane fractures were found in 38% of the distal femoral intra-articular fractures. All these combined fractures have to be invariably labeled as C3 type or multifragmentary articular fractures. The term multifragmentary is very subjective. What actually accounts for multifragmentary is not understood by the classification. The C3 type is further subclassified into C3.1, C3.2, and C3.3. However, all these subtypes focus on metaphyseal comminution and not articular fragments. A detailed CT-based evaluation irrespective of the degree of metaphyseal comminution is essential in all intra-articular fractures. CT will not only help in the proper identification of fracture fragments, but it will also help in planning the surgery and implant selection. Moreover, we found it difficult to classify a few fractures using the AO OTA system. One example is a combined sagittal and coronal plane fracture of an isolated medial or lateral condyle.

Although there is a consensus in the literature regarding the validity of AO OTA classification for distal femur fractures, there are a few studies that highlight the problems with it. Elsoe et al. conducted a population-based epidemiological study of distal femur fractures among Danish patients [10]. They found that approximately 10 % of the total distal femur fractures could not be classified using the AO Classification. They have subclassified this group as the Missing AO group. Similarly, Agrawal and Kiyawat conducted a study on the management of complex distal femur fractures [11]. The inability of the AO classification system to classify these fractures is very evident by the fact that they have used two sub-classifications for extra-articular and intra-articular parts of the same fracture. Bagaria et al. proposed a new classification system for the coronal plane fractures of the distal femur [12]. They have suggested a separate subclass for combined coronal and sagittal fracture of the femoral condyle, which could not be classified by the AO system. These studies highlight the necessity of a CT-based classification system.

Based upon these needs, we have described a classification

system which is CT-based and provides a complete description of the articular fragments. This classification is based upon the planes of the fracture lines. Type A is a uniplanar sagittal fracture, and type B is a uniplanar coronal fracture. Type C, D, E, and F represent biplanar fractures with increasing grades of comminution. This classification system helps us in deciding the approach to the fracture and also helps in prognostication of fractures as well. Fractures with increasing degrees of articular comminution have less post-operative ROM, and there are increased chances of arthritis; e.g., type C has a better prognosis than type F. A metaphyseal fracture classification system is also added to the articular fracture classification. M1 is simple, M2 is comminuted, and M3 is associated with bone loss. A description of the applicability of the classification in terms of approach, surgical planning, implant selection, and prognosis is provided in Table 3.

Limitations

The sample size of this study is very small. This classification

system requires large group studies to assess its validity and reliability.

Conclusion

Thus, we conclude that this CT-based classification system is a focused tool to assess the degree of severity of the articular comminution, plan our approach to the fracture, decide the implants necessary, and grade the prognosis. Simultaneously, this classification provides an addition to the metaphyseal comminution, which can be written together. In spite of being very elaborate, it is easy to reciprocate and communicate.

Clinical Message

This classification helps young surgeons who have little experience to understand the pattern of fracture, plan for fixation of the fragments, determine the types of implants needed, anticipate intraoperative difficulties, and be ready with armamentarium.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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