The Floating Knee Injuries: Does it Need a New Classification System?

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Abstract

Background This study aims to determine the differences between the clinical and radiological results of patients based on Karlstrom–Olerud Scoring System who cannot be included in any classification for floating knee injuries and to seek an answer to the question of whether a new classification is needed.

Material and Methods Seventy patients with floating knee injuries treated in our clinic were retrospectively analyzed between 2008 and 2019 in the study. The results of fractures that classifiable and unclassifiable according to the Fraser, Blake and McBryde classifications were statistically compared based on the Karlstrom–Olerud criteria.

Results Seventy patients, 64 males and 6 females, participated in the study. The mean age of our patients was 32.3 ± 12.55 (18–68) years. The mean follow-up period of the patients was 30.26 ± 18.19 months (11–60 months). The results of the fractures that could not be classified according to the Blake and McBryde classification were statistically poorer than the results of those that could be classified according to the criteria ($p=0.041$).

The results of the fractures that could not be classified according to the Fraser classification were statistically poorer than the results of those that could be classified according to the criteria defined by Karlstrom and Olerud ($p=0.010$).

Conclusion We observed that floating knee injuries that we could and could not classify led to different clinical results. In conclusion, we think that there is a need for a new floating knee classification that includes segmental fractures, patellar fractures and open fractures.

Keywords Floating knee · Classification · Trauma · Ipsilateral · Femur · Tibia

Introduction

Floating knee injuries were described for the first time in 1975 by Blake and McBryde have been of interest since that time [1]. The treatment of floating knee injuries, which are generally caused by high energy traumas, requires a good planning of treatment. In the literature, studies report both favorable and unfavorable results based on the preferred treatment method [2–6]. We think that different treatment results reported in the literature

are due to the differences in the management of patients' treatment processes. While planning our study, we realized that some fractures could not be classified according to the current classification systems used for floating knees. Considering that the classifications provide guidance for treatments and facilitate planning, whether a new classification is needed springs to mind. Common classification systems for floating knee injuries are the Fraser, Modified Fraser and Blake and McBryde, Letts and Vincent and Bohn Durbin classification systems [1, 2, 7]. These systems provide informations for surgeons who treat the floating knee injuries. Letts and Vincent and Bohn Durbin classification are suitable for pediatric floating knee injuries which classify region and type of the fracture. Blake and McBryde classify fractures as Type I, IIA–IIB. Type I involves the fracture of femur and tibia and IIA involves the knee joint and IIB involves the hip and ankle joints. Fraser et al. further classify floating knee injuries as Type I: shaft fractures of femur and tibia without the involvement of either fracture into the

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knee, Type II fractures extended into the knee and were further sub-divided. Type IIa involved the tibial plateau, type IIb included the distal femur into the knee, and type IIc involved both the tibial plateau and the distal femur within the knee joint [2]. Modified Fraser classification system involves patella fracture in floating knee injuries.

Our aim in this study is to compare the clinical and radiological results of patients with floating knee injuries that can be classified using the Fraser, Blake and McBride classification and also cannot be classified using this classification based on Karlstrom–Olerud scoring system [8] and to seek an answer to the question of whether a new classification is needed.

Materials and Methods

This is single center, retrospective analysis of patients who were diagnosed as floating knee injury between 2008 and 2019 in our university. The study started after obtaining the approval from the ethics committee of our university. All the 70 patients included for the study had a good follow-up period. Pediatric patients, patients without floating knee injury, and patients without adequate follow-up were excluded from the study.

All fractures were classified using the Fraser and Blake and McBryde classifications for floating knee injuries. The patients presenting with open fractures were classified according to the Gustilo-Anderson classification. The first interventions of the patients with floating knee injuries who presented with open fractures were performed in the emergency department. All patients were evaluated whether they had neurovascular and additional systems injury. After the first view in emergency department, patients were prepared for surgical procedures. They were operated after wound irrigation, antibiotherapy and temporary splinting in emergency departments. Antibiotherapy protocol was for clean wounds 1. Generation cephalosporin (1 g) before operation procedure, if the wound was not clean aminoglikozid (160 mg 1 × 1) and ornidazole (2 × 500 mg) were added. Then external fixation was performed for open fractures. Considering that the risk of wound infection (normal sedimentation—crp—wbc counts and no drainage and wound infection signs after 2 weeks from injury) was reduced in open fractures, internal fixation was performed. Radiological follow-up of all patients was performed with X-rays taken 1 month, 3 months, 6 months and 1 year after the injury.

The localization of the fractures, the presence of accompanying injuries, whether union developed, and fracture fixation material were recorded. And the results were analyzed according to Karlstrom–Olerud criteria. The results of fractures that did not fit both classifications and fractures

that could be classified according to the Fraser, Blake and McBryde classifications were statistically compared based on the Karlstrom–Olerud criteria (Table 1).

Statistical Analysis

The statistical package program Statistical Package for the Social Sciences (SPSS) 11 for Windows was used in statistical calculations. Data are described as arithmetic mean and standard deviation. The Chi-square distribution test was used for the calculation of categoric variables, and the Mann–Whitney *U* test was used for the comparison of means. “*p* values” lower than 0.05 were accepted as significant.

Results

Seventy patients, 64 males and 6 females, participated in the study. The mean age of our patients was 32.3 ± 12.55 (18–68) years. The mean follow-up period of the patients was 30.26 ± 18.19 months (11–60 months).

Of the patients, 33 suffered from fracture in the left lower extremity and 37 suffered from fracture in the right lower extremity. Of the patients, 49 were injured as a result of a traffic accident, 13 were injured by a firearm, and 8 were injured as a result of fall from height.

Of the femoral fractures, 41 were only fixed with intramedullary nails. Twelve patients underwent fixation with a plate only. External fixators were used for the femurs of 27 patients. External fixator was used as permanent fixation in 5 fractures, while the other 22 patients were operated for the second time for permanent fixation.

Of the tibia fractures, 26 were fixed with an intramedullary nail and 20 with a plate. Fixator was used for permanent fixation in 14 of 24 patients for whom external fixator was used. Accompanying patella fractures were operated using the tension band technique. Twelve patients had concomitant injuries (abdominal, head and thoracic injuries).

Of the fractures, 25 were closed (both femur and tibia), and 45 were open (femur or tibia). The open fracture analysis performed according to the Gustilo-Anderson classification is summarized in Table 2.

Of the patients, 16 had segmental fractures (Fig. 1). Of these, 11 had segmental fractures only in the femur, 2 only in the tibia, and 3 both in the femur and tibia. Ten patients had patellar fractures. Of these ten patella fractures, seven were on the articular surface of the femur or tibia. In three patients, the articular surface of the femur and tibia was intact. Of the femoral fractures, 31 were femoral shaft fractures, 18 were femur distal fractures, 9 were femoral sub-thoracentric fractures, 1 was femoral neck fracture, and 11 were segmental femur fractures. Of the tibia fractures, 43

Table 1 Patients demographics

Sütun 1 Classification	Sütun 2	Sütun 3	Sütun 4	Sütun 5	Sütun 6	Sütun 7	Sütun 8	Sütun 9
Case	Age	Gender	Open-closed fractures (femur/ tibia) (Gustilo Anderson Class.)	Fraser	Blake and McBryde	Patella fracture	Union	Results (Karl- strom–Olerud criteria)
1	65	M	Closed	Unclassified	Unclassified	Yes	+	Excellent
2	68	M	Closed	Unclassified	Unclassified	No	+	Good
3	37	F	Tip 3B/Tip 3B	Tip 1	Tip 1	No	+	Poor
4	40	M	Closed	Unclassified	Unclassified	No	Nonunion (femur)	Acceptable
5	25	M	Closed	Tip 1	Tip 1	No	+	Good
6	39	M	Closed	Unclassified	Unclassified	No	+	Acceptable
7	19	M	Closed/Tip 3A	Tip 1	Tip 1	No	+	Poor
8	35	F	Closed	Unclassified	Unclassified	No	+	Good
9	34	F	Closed	Unclassified	Unclassified	No	+	Good
10	27	M	Closed	Tip 1	Tip 1	No	+	Good
11	36	F	Tip 2/Tip 2	Unclassified	Unclassified	Yes	Nonunion (femur)	Poor
12	15	M	Closed/Tip 2	Unclassified	Unclassified	No	+	Good
13	21	M	Closed/Tip 3A	Tip 1	Tip 1	No	+	Good
14	37	F	Closed	Unclassified	Unclassified	No	+	Good
15	50	M	Tip 3A/Tip 3A	Unclassified	Unclassified	Yes	Knee arthrodesis	Poor
16	25	M	Closed	Tip 1	Tip 1	No	+	Good
17	47	M	Closed	Tip 2a	Tip 2b	No	Nonunion (femur)	Poor
18	28	M	Tip 3A/Tip 2	Unclassified	Unclassified	Yes	+	Poor
19	48	M	Closed/Tip 3B	Unclassified	Tip 2b	No	Ankle arthrodesis	Poor
20	34	M	Tip 2/Closed	Unclassified	Unclassified	No	+	Acceptable
21	24	M	Closed	Tip 1	Tip 1	No	+	Good
22	40	M	Tip 3A/closed	Tip 1	Tip 1	No	+	Good
23	35	M	Tip 1/Tip 2	Tip 1	Tip 1	No	+	Good
24	28	M	Tip 3A/Tip 3B	Tip 1	Tip 1	No	+	Good
25	25	M	Tip 2/Tip 3C	Unclassified	Unclassified	No	Amputation	Poor
26	39	M	Closed	Tip 2a	Tip 2a	No	+	Acceptable
27	27	M	Closed	Tip 1	Tip 1	No		Good
28	21	M	Closed	Tip 1	Tip 1	No	Nonunion (femur)	Poor
29	49	M	Closed	Unclassified	Unclassified	No	+	Excellent
30	30	M	Closed/Tip 2	Tip 1	Tip 1	No	+	Acceptable
31	25	M	Closed	Tip 2a	Tip 2a	No	+	Excellent
32	57	M	Tip 3A/Tip 3A	Unclassified	Unclassified	Yes	Nonunion (femur ve tibia)	Poor
33	25	M	Closed/Tip 3B	Tip 1	Tip1	No	+	Good
34	18	M	Tip 3A/Tip 3A	Unclassified	Unclassified	Yes	Knee arthrodesis	Poor
35	16	M	Tip 1/closed	Tip 1	Tip 1	No	+	Excellent
36	31	M	Tip 3B/Tip 3B	Unclassified	Unclassified	Yes	Knee arthrodesis	Poor
37	18	M	Tip 1/Tip 3C	Tip 1	Tip 1	No	+	Acceptable
38	18	M	Tip 3A/Tip 3A	Unclassified	Unclassified	Yes	+	Acceptable
39	39	M	Tip 3C/Tip 3C	Tip 2c	Tip 2a	No	+	Poor
40	58	F	Closed/Tip 3A	Tip 1	Tip 1	No	+	Good
41	33	M	Tip 3B/Tip 3B	Unclassified	Unclassified	Yes	Amputation	Poor
42	26	M	Closed	Unclassified	Unclassified	No	+	Good
43	27	M	Closed/Tip 3A	Tip 1	Tip 1	No	+	Poor

Table 1 (continued)

Sütun 1 Classification	Sütun 2	Sütun 3	Sütun 4	Sütun 5	Sütun 6	Sütun 7	Sütun 8	Sütun 9
Case	Age	Gender	Open-closed fractures (femur/ tibia) (Gustilo Anderson Class.)	Fraser	Blake and McBryde	Patella fracture	Union	Results (Karl- strom–Olerud criteria)
44	41	F	Tip 3A/Tip 3A	Unclassified	Unclassified	Yes	Knee arthrodesis	Poor
45	37	M	Closed/Tip 3A	Unclassified	Unclassified	No	Nonunion (Tibia)	Acceptable
46	25	M	Tip 2/Tip 2	Tip 1	Tip 1	No		Acceptable
47	24	M	Tip 2/Tip 3C	Tip 1	Tip 1	No	Knee disarticulation	Poor
48	53	M	Tip 2/Tip 2	Tip 2c	Tip 2a	No	+	Acceptable
49	31	M	Tip 3A/Tip 3A	Tip 2b	Tip 2a	Yes	+	Good
50	29	M	Closed	Tip 1	Tip 2a	No	+	Excellent
51	18	F	Closed	Tip 1	Tip 1	No	+	Excellent
52	31	M	Tip 2/Tip 2	Tip 2b	Tip 2a	Yes	+	Good
53	48	M	Tip 2/Tip 3A	Unclassified	Unclassified	Yes	+	Acceptable
54	38	M	Closed	Tip 1	Tip 1	No	+	Excellent
55	25	M	Tip 3C/Tip 3C	Unclassified	Tip 2b	Yes	+	Good
56	20	M	Closed	Tip 1	Tip 1	No	Nonunion (tibia)	Acceptable
57	50	M	Tip 3A/Tip 3B	Tip 2b	Tip 2a	No	+	Good
58	31	M	Tip 1/Tip 2	Unclassified	Unclassified	No	Nonunion (femur)	Poor
59	39	M	Tip 3C/Tip 3C	Tip 2b	Tip 2b	No	+	Good
60	16	M	Closed	Tip 1	Tip 1	No	+	Excellent
61	18	M	Tip 3C/Tip 3C	Tip 1	Tip 1	No	+	Excellent
62	24	M	Tip 3A/closed	Unclassified	Tip 2b	No	+	Excellent
63	16	M	Closed	Tip 1	Tip 1	No	+	Excellent
64	27	M	Closed/Tip 2	Tip 1	Tip 1	No	+	Excellent
65	33	M	Closed	Tip 1	Tip 1	No	+	Excellent
66	59	M	Tip 3A/Tip 3A	Tip 2c	Tip 2a	Yes	+	Poor
67	23	M	Tip 3A/Tip 3B	Tip 2b	Tip 2a	No	+	Good
68	18	M	Closed/Tip 2	Tip 1	Tip 1	No	+	Excellent
69	18	M	Closed/Tip 2	Tip 2b	Unclassified	No	+	Excellent
70	31	M	Closed/Tip 2	Tip 2b	Unclassified	No	+	Excellent

Table 2 Types of open fractures

Gustilo-Anderson classification	Femur	Tibia
Type I	4	–
Type II	8	13
Type IIIA	13	13
Type IIIB	3	8
Type IIIC	4	7

were tibia shaft fractures, 17 were tibial plateau fractures, 5 were segmental tibial shaft fractures, and 5 were tibia distal fractures.

Eight of the 70 patients with ipsilateral femur and tibia fractures had non-union and the characteristics of non-union fractures were summarized (11.4%) (Table 3).

Five of the 70 patients underwent arthrodesis due to the failure to achieve joint reconstruction. Four of the arthrodeses were knee arthrodeses and one was ankle arthrodesis. Four patients who underwent knee arthrodesis had accompanying patellar fractures and patients who were performed arthrodesis had open fractures. All patients who underwent knee arthrodesis had Type III open fractures in both the tibia and femur. The patient who underwent ankle arthrodesis had a Type III open fracture in the tibia and an intraarticular fracture in the talus. All arthrodesis procedures were not primary arthrodesis.

Fig. 1 Segmental femur fracture, tibia proximal fracture treatment with intramedullary nail and plate

Two of the 70 patients underwent below-knee amputation because major popliteal artery injury and while one underwent knee disarticulation.

Of the patients, 16 (22%) were evaluated as excellent, 23 (32.8%) as good, 12 (17.1%) as acceptable and 19 (27.1%) as poor according to the criteria defined by Karlstrom and Olerud.

The analysis of the fractures included in the study according to the floating knee classification system developed by Fraser et al. was summarized (Table 4).

The analysis of the fractures according to the classification system developed by Blake and McBryde was summarized (Table 5).

The results of the fractures that could not be classified according to the Blake and McBryde classification were statistically poorer than the results of those that could be classified according to the criteria defined by Karlstrom and Olerud ($p=0.041$).

The results of the fractures that could not be classified according to the Fraser classification were statistically poorer than the results of those that could be classified according to the criteria defined by Karlstrom and Olerud ($p=0.010$).

The results of the open fractures were poorer than the results of closed fractures ($p=0.004$).

The results of the floating knee injuries accompanied by patellar fracture were also poorer than the results of the patients with knee injuries with an intact patella ($p=0.003$).

Discussion

Previous studies have shown that the results of floating knee injuries can be affected by the complexity of fracture and condition of soft tissues [4, 9]. Fracture classification

Table 3 Characteristics of non-union fractures

Case	Non-union bone	Gustilo-Anderson classification (femur/tibia)	Blake and McBryde classification	Fraser classification	Type of fracture	Accompanying patellar fracture	Treatment (femur/tibia)	Results
1	Femur	Closed/closed	Unclassified	Unclassified	Segmental	None	Imn + plate/plate	Acceptable
2	Femur	Type II/Type II	Unclassified	Tip 2a	Intraarticular	Yes	Plate/Imn	Poor
3	Femur	Closed/closed	Type 2A	Unclassified	Intraarticular	None	Plate/Ext. Fix	Poor
4	Femur	Closed/closed	Type I	Unclassified	Extraarticular	None	Imn/Imn	Poor
5	Femur + tibia	Type IIIA/type IIIA	Unclassified	Unclassified	Segmental	Yes	Plate/Ext. Fix	Poor
6	Tibia	Closed/type IIIA	Unclassified	Unclassified	Segmental	None	Imn/Imn	Acceptable
7	Femur	Type I/type II	Unclassified	Tip 1	Segmental	None	Ext. Fix./Ext. Fix	Poor
8	Tibia	Closed/closed	Type I	Tip 1	Extraarticular	None	Plate/plate	Acceptable

Table 4 Distribution of patients by Fraser classification

Fraser classification	Number of patients
Type 1	29
Type 2A	4
Type 2B	7
Type 2C	3
Not classifiable	27

Table 5 Distribution of patients by Blake and McBryde classification

Blake and McBryde classification	Number of patients
Type 1	29
Type 2A	12
Type 2B	3
Not classifiable	26

systems play a key role in choosing the treatment to be used and predicting the prognosis. There are two generally adopted classification systems used for floating knee injuries: the classification defined by Blake and McBryde and the classification defined by Fraser et al. [1, 2]. Floating knee injuries accompanied by segmental fractures and patellar fractures are not included in either current classification systems. The presence of complex fractures and accompanying soft tissue injury along with extensor mechanism problems make floating knee injuries even more complex. In the literature, studies report that the presence of open fractures, accompanying segmental fractures, and the presence of intraarticular fractures lead to poor results [10]. In this study, we examined the clinical results of the differences in floating knee injuries that can and cannot be classified according to the classification systems.

Although numerous classification systems are available, the clinical results of patients with floating knee injuries are classified according to the Karlstrom–Olerud criteria [8]. In our study, the results of both classified and not classifiable fractures were classified according to the same criteria. The results of not classifiable fractures were statistically poorer according to both classifications.

Floating knee injuries accompanied by segmental fractures and patellar fractures are not included in either current classification systems. Of our patients included in the study, 27 and 26 patients could not be included in both classification systems according to the Fraser and Blake and McBryde classification systems, respectively.

Ten patients had accompanying patellar fracture. Eight of these patients were evaluated as "poor" according to the Karlstrom–Olerud criteria. Ran et al. [7] stated that

the patella was an important structure for the extensor mechanism, and patellar fractures should be included in the classification. In our study, we also revealed that the patients with accompanying patellar fractures had poorer clinical results according to the Karlstrom–Olerud criteria. We propose that the presence of patellar fracture should be included in the classification through its effect on the results.

In our study, the results of the open fractures were poorer than the results of closed fractures. Of our patients, 45 had open fractures in the femur or tibia according to the Gustilo–Anderson classification. In the literature, several studies report that floating knee injuries accompanied by open fractures also lead to poor results [11]. On the other hand, high-energy trauma should be considered even in patients who are evaluated to have closed fractures.

Moreover, ligamentous knee injuries are among the pathologies accompanying floating knee injuries. Doyle et al. [12] stated that the poor functional result of floating knee injuries was due to the delayed diagnosis of ligamentous knee injuries. We did not evaluate ligamentous knee injuries in our study, and we do not know their effect on the results, which may be described as one of the limitations of our study.

High complication rates accompany floating knee injuries [9]. In our study, some patients underwent knee arthrodesis, ankle arthrodesis and amputation due to the problems caused by these complications. Another problem we encountered during the follow-up periods was non-union. Non-union was observed in 11% of our cases. Half of the patients with non-union had open fracture, while the other half had closed fractures. Five of the eight patients were included in the non-classifiable group and had non-union fractures.

Our study had several limitations. First, the study data were collected retrospectively. Knee ligament injuries were not analyzed and not included in the results. We do not know whether ligament injuries had an effect on the results. On the other hand, our study did not investigate the effect of data on the results such as the implant used, surgical technique, the number of sessions and operations the patient underwent.

Conclusion

Upon the data we obtained, we observed that floating knee injuries that we could and could not classify led to different clinical results. In conclusion, we think that there is a need for a new floating knee classification that includes segmental fractures, patellar fractures and open fractures.

Compliance with Ethical Standards

Conflict of interest Burçin Karşı, Sezgin Bahadır Tekin declare that they have no conflict of interest.

Ethical Standard Statement The study protocol was approved by Scientific Research Ethics Committee of Gaziantep University Medical Faculty and the study was conducted in accordance with Declaration of Helsinki.

Informed Consent For this type of study informed consent is not required.

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