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Floating knee: A new prognostic classification

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ABSTRACT

Introduction: Usually ipsilateral fractures of the femur and tibia are not compatible with good results and require surgery. The unsatisfactory results are more likely due to complex patterns of fractures, compromised soft tissue, associated ligament injuries, and concomitant vital organ injuries. There are many classifications to describe this type of fracture but none of them is a prognostic classification. The aim of this study is to validate our classification according to prognostic terms.
Methods: This retrospective study encloses patients accepted with a diagnosis of floating knee between January 1st 2014 and December 31th 2020. A total of 372 patients met the inclusion criteria, but only 168 patients were selected for the final review. We have reclassified the 168 patients into three classifications: according to our alphanumeric; according to the Fraser classification; according to Letts and Ran. Our classification is divided into 5 macro categories in increasing order of severity, and considering fracture site, and exposure status. The Tau B Kendall and Cohen's Kappa was used to statistically evaluate the prognostic value, reliability and reproducibility of our classification versus Fraser Classification, Letts and Ran Classification in the prognosis of these injuries.
Results: The statistical results showed that classifiying patient into macro category and sub-category it is possible to have a prognostic correlation with functional results. Noteworthy, floating knee is a complex injury with poor results.
Conclusion: The floating knee is not only the bone lesion but is above all the lesion of the soft tissues and the extensor apparatus that allow the correct functionality of the knee. These lesions do not always have favorable outcome, with respect to the nonseverity of the lesion as in Fraser's classification. Furthermore, on average these patients are subjected to an average of 6 surgical interventions; in some cases we have assisted to 23 surgical procedures. This study proved that this new classification system is prognostic, reliable and reproducible.

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Introduction

Floating knee is a flail knee joint resulting from fractures of the shafts or adjacent metaphyses of the femur and the ipsilateral tibia. It is usually associated with several complications and mortality.

This severe injury appears to be increasing in frequency, with a male preponderance observed, particularly in young adults between 20 and 30 years [1]. Road traffic accidents are the most common mechanisms of trauma, followed by gunshot wounds and falls from high heights [1].

The floating Knee is a surgical challenge for traumatologist or orthopedics [1].

In fact, the floating knee is characterized by infinite variables as the various types of fractures of the tibia and femur, meniscal ligament injuries, soft tissue, degrees of open fracture, bone loss, soft tissue injuries, dislocations, injuries of the extensor apparatus are multiplied. knee and etc. [2–6].

The unsatisfactory results are more likely due to complex patterns of fractures, compromised soft tissue, associated ligament injuries, and concomitant vital organ injuries [1,2].

There are many classifications to describe this type of fracture but none of them is a prognostic classification [2–6].

The aim of this study is to validate our classification according to prognostic terms.

Materials and methods

This retrospective study encloses patients accepted with a diagnosis of floating knee between January 1st 2011 and December 31th 2020 at Department of Orthopedics and Traumatology, AORN San Pio Hospital, Benevento, Italy. Patients were treated according to the Helsinki Declaration of Ethical Standards. They were asked to read and understand the patient information sheet about knee fractures and sign the informed consent form at hospital admission.

Given the retrospective nature of this study, ethical committee approval was not necessary. Inclusion criteria were the presence of a floating knee fracture pattern with an indication for surgical or conservative treatment, male patients >70 years, female patients >65 years, polytrauma patients who were alive at presentation and survived to their injuries, and a minimum 36- month follow-up.

Exclusion criteria were: patients whose follow-up was discontinued, patients with a history of metabolic bone diseases or other bone diseases, and patients with history of malignancy and pathological fractures.

A total of 372 patients met the inclusion criteria, but only 168 patients were selected for the final review. We have reclassified the 168 patients into three classifications: according to our alphanumeric (see Table 1 and Fig. 1A and B); according to the Fraser classification [1–6]; according to Ran et al. [6].

According to the Gustilo Anderson Classification [1–6] classification, (from grade I, four to grade IIIC) were open.

For each patient, a preoperative x-ray in anterior-posterior and lateral views and CT scan were performed to assess proper surgical planning and any ligamentous or meniscal injuries. An MRI was not carried out preoperatively to avoid surgical delay.

The patients were clinically assessed for knee ligament lesions after fixation of the fractures intra-operatively. Functional exercise varied widely depending on the stability achieved and the implants used.

All the authors repeated the classification session two times with at least 3 days between the repeated measurements.

On X-ray the complete healing of the fracture and the presence of complications like, arthrosis, non-union or malunion and post sequelae of ligamentous or meniscal injuries were assessed. All complications were recorded.

The clinical results were evaluated according to the objective/subjecive criteria established by Karlstrom and Olerud [7].

A follow-up evaluation, which included a clinical, radiographic assessment including MRI, was performed at 36 months.

Statistical analysis

The Kendall Tau-B correlation between the Karlstrom and Olerud scores at the last follow-up and the new classification, the Fraser's classification [1–6] and the Ran's classification [4], was used to assess the prognostic value of each types of fracture we evaluated. A multivariate analysis using the multiple regression with backward Wald method was then performed to detect factors (sex, age, associated esions, type of surgery, etc.) other than classifications to predict Karlstrom and Olerud. The General Linear Model (GLM), with Karlstrom and Olerud as the dependent variable and the classifications as covariates, was finally performed to compare the prediction strength of each classification. The partial eta squared was used to measure the prediction strength.

To investigate the reliability of the classification systems we evaluated the interobserver agreement for each method of classification using the weighted Kappa statistics described by Fleiss [8,9].

The three Kappa statistics were then compared using the Wald test. In order to evaluate the reproducibility of the new proposed classification system we calculated the intra-observer agreement using the Kappa statistics.

Data analysis was performed using SPSS1 software version 21 (SPSS Inc., Chicago, IL). The Wald test was performed according to Shoukri et al. [10].

The literature proposes the following classification for K value: less than 0.4 poor agreement, from 0.4 to 0.6 moderate agreement, from 0.6 to 0.8 good agreement and from 0.8 to 1 excellent agreement [11].

Results

Clinical details of 168 floating knees Table 2

168 patients, 140 males and 28 females, were included in the study, their average age was 32.4 ± 16.1 years (16–60). The mean follow up was 7.4 ± 4.7 years (3–18).

Road traffic accidents accounted for 120 patients (71.43%), agriculture accidents accounted for 21 patients (12.50%), 8 patients (4.76%) injured after falling from height while other type of accidents accounted for 19 patients (11.31%).

Out of the 168 examinated patients, 95 (56,55%) had open fractures, for a total of 125 open fractures defined by Gustilo Anderson (GA) classification: 22 GA1, 47 GA2, 24 GA3A, 20 GA3B, 12 GA 3C. There were 61 open fractures of the tibia, 45 open fractures of the femur, 4 open fractures of the fibula, 15 open fractures of the tibia and fibula.

The average Injury severity score (ISS) was 29.1 ± 16.8 (12–54) while Average Glasgow Coma Score (GCS) was 11.2 ± 3.8 (6–15)

22 patient occures with a subamputated limbs (13,10%) and the

Table 1
The new prognostic outcome classification of Floating Knee.

Numeric	Description
I	Fracture of the shaft of the Femur and Tibia
II	Femur Diaphysis Fracture, proximal meta- epiphyseal articular fracture of the tibia;
III	Distal Meta-epiphyseal articular Fracture of Femur and Tibial Diaphysis Fracture
IV	Meta- epiphyseal articular fractures of the Femur and Tibia
V	Rupture of the extensor apparatus associated with any of the four previous types of injuries.
Alfa	
A	Closed trauma with or without ligament rupture or chondral or meniscal damage
B	Multi-ligament rupture and chondral or meniscal damage, or exposure of a segment within grade IIIA according to
C	Grade IIIB exposure of one segment, Exposure of both segments, Bone loss, Vascular and Nerve damage, Subamputated limb.

Average Mangled Extremity Severity (M.E.S.S.) in limb subamputed with Not plantar reflex presence was 9.4 ± 1.2 (8–11)

There were 20 patients with an Injuries of the Extensor Apparatus (11,90%): 12 Patella fracture (60.00%), 2 Quadriceps Muscle ruptures (10.00%), 6 Quadriceps Tendon ruptures (30.00%), 7 Patellar Tendon ruptures(35.00%), 1 Quadriceps Tendon Patellar Tendon rupture (5.00%).

132 Patients had Knee's Soft Tissues Injuries (78,57%) as reported in Table 2: 48 Lateral Meniscus Injuries (28.57%), 86 Medial Meniscus Injuries (51.19%), 24 Posterior Cruciate Injuries (14.29%), 77 Anterior Cruciate Injuries (45.83%), 68 Medial Collateral Ligament (40.48%),84 Lateral Collateral Ligament (50%).

Compartimental syndrome occured in 13 cases (7,74%).

The mean Non-Union Scoring System (NUSS) points was 26.4 ± 22.3 (0–61). There were 23 patients (13,70%) with nonunion that involed only femur in 5 cases (21.74%), only Tibia in 15 (65.22%), Femur and Tibia: in 3(13.04%).

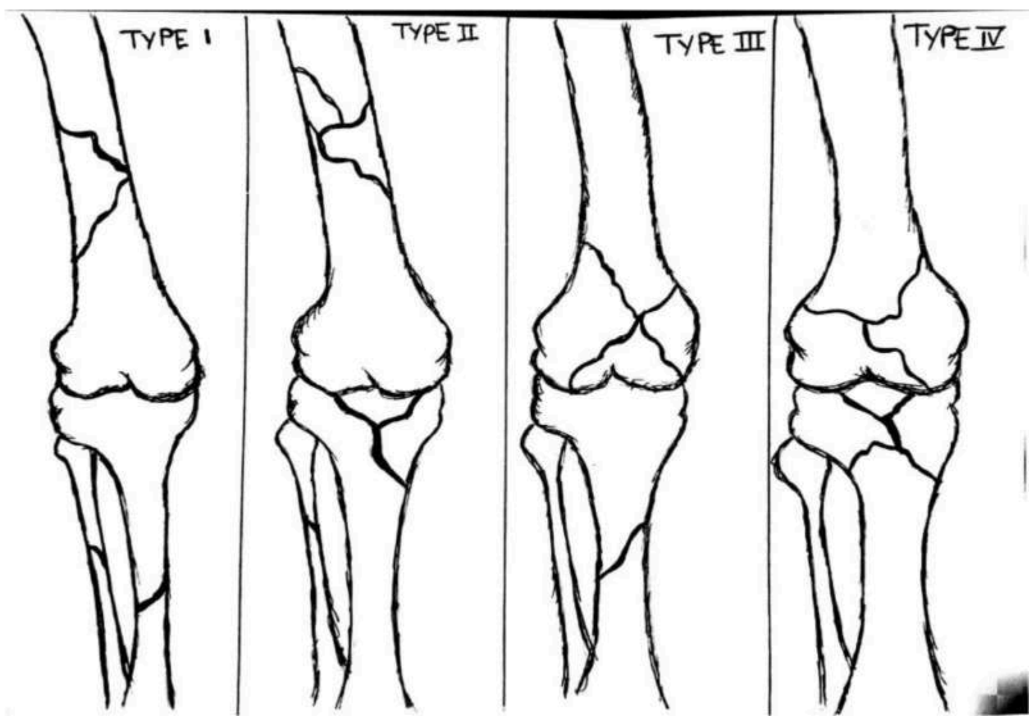
Patients with Mal Union were 30(17.86%): Only Femur involed in 10 cases (33.33%), Only Tibia involed in 15(50%), Femur and Tibia involed in 5(16.67%).

Out of the 12 patients that have developed Infections (7,43%), 8 were osteomyelitis (66,67%) while 4 were having deep infection of soft tissue (33.33%).

Average surgical treatments per patient during the follow up was 9.9 ± 7.4 (2–22)

At least 18 patients were amputated (10,72%) at different levels as described in Table 2: 4 Trans Femoral (22.22%), 13 Trans Tibial (72.22%), 1 Disarticulation (5.56%).

Each fracture was classified by all 3 different classification systems (Our new prognostic classification, Fraser's Classification and Ran's Classification) as reported in Table 2.



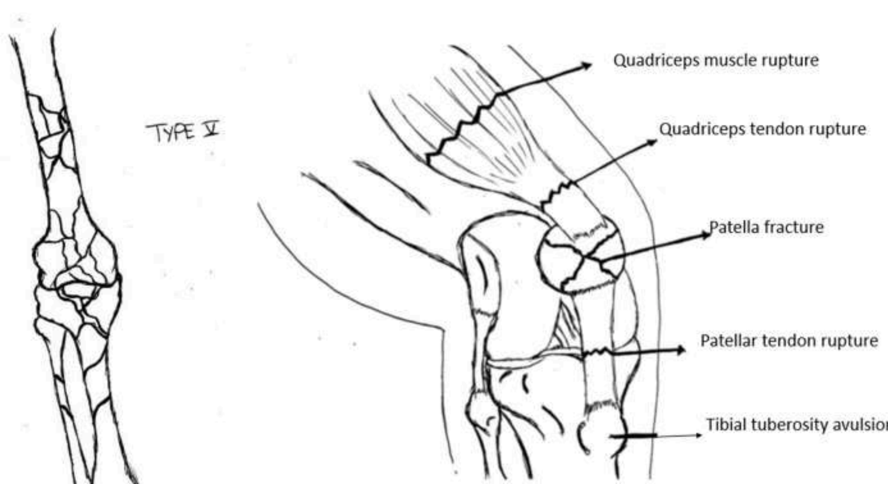


Fig. 1. A: Drawing of new system classification: I. Fracture of the shaft of the Femur and Tibia; II. Femur Diaphysis Fracture, proximal meta- epiphyseal articular fracture of the tibia; III. Distal Meta-epiphyseal articular Fracture of Femur and Tibial Diaphysis Fracture; IV. Meta- epiphyseal articular fractures of the Femur and Tibia. B: Drawing of new system classification: V. Rupture of the extensor apparatus associated with any of the four previous types of injuries.

Table 2
Clinical details of 168 floating knees.

Numbers of patients	168
Average Age Of Patients (SD)	**32.4 ± 16.1**
Range Of Age Of Patient	**16–60**
Gender Ratio (M:F)	**5:1 (140:28)**
Range of Ages	16–35: **82 (48.81%)** 36–50: **54 (32.14%)** 51–59: **22(13.10%)** >60: **10 (5.95%)**
Work Of Population:Number (%)	Agricultural Sector: **60 (35.71%)** Industrial Sector: **72 (42.85%)** Tertiary Sector: **36 (21.44%)**
Type Of Accident: Number (%)	Fall From Height: **8 (4.76%)** Traffic Accident: **120 (71.43%)** Accident Agriculture: **21 (12.50%)** Other Accident: **19 (11.31%)**
Patient with Open/Cloed Fractures Ratio	**5:1 (95:71)**
Patients Open Fractures: Number (%)	**95 (56.55%)**
Number of Open Fractures	**125**
Site of Open Fractures	Femur: **45 (36.00%)** Tibia: **61 (48.80%)** Fibula: **4 (3.20%)** Tibia & Fibula: **15 (12.00%)**
Open fractures in Femur & Lower Leg (n)	**43**
Gustillo Anderson Classification n(%)	Type I: **22 (17.60%)** Type II: **47 (37.60%)** Type IIIA: **24 (19.20%)** Type IIIB: **20 (16.00%)** Type IIIC: **12 (9.60%)**
Average NUSS points (range,SD)	**26.4 (0–61; ± 22.3)**
Patient with Compartimental Syndrome: Number (%)	**13 (7.74%)**
Patient with Subamputed Limbs:Number (%)	**22 (13.10%)**
Average Injury Severity Score (ISS);(range, SD)	**29.1 (12–54; ± 16.8)**
Average Glasgow Coma Score (GCS); (range, SD)	**11.2 (6–15; ± 3.8)**
Average Mangled Extremity Severity (M.E.S.S.) in limb subamputed with Not plantar reflex presence;(range,SD)	**9.4 (8–11; ± 1.2)**
Patients with Extention Apparatus of Knee Injuries n (%)	**20 (11.90%)**
Type of Extention Apparatus of Knee Injuries n (%)	**Patella: 12 (60.00%)** **Quadriceps Muscle: 2 (10.00%)** **Quadriceps Tendon: 6 (30.00%)** **Patellar Tendon: 7 (35.00%)** **Quadriceps Tendon Patellar Tendon: 1 (5.00%)**
Patients with Knee's Soft Tissues Injuries NUMBER (%)	**132 (78.57%)**
Knee's Soft Tissues Injuries NUMBER (%)	**Lateral Meniscus Injuries: 48 (28.57%)** **Medial Meniscus Injuries: 86 (51.19%)** **Posterior Cruciate Injuries: 24 (14.29%)** **Anterior Cruciate Injuries: 77 (45.83%)** **Medial Collateral Ligament: 68 (40.48%)** **Lateral Collateral Ligament: 84 (50%)**
Patients with Non Union n (%)	**23 (13.70%)** Only Femur: **5 (21.74%)** Only Tibia: **15 (65.22%)** Femur&Tibia: **3 (13.04%)**
Patients with Mal Union n (%)	**30 (17.86%)** Only Femur: **10 (33.33%)** Only Tibia: **15 (50%)** Femur&Tibia:**5 (16.67%)**
Patients with Infections n (%)	**12 (7.43%)** Osteomyelitis: **8 (66.67%)** Deep Soft Tissue Infection: **4 (33.33%)**
Patients with Leg Amputation as last surgery n (%)	**18 (10.72%)**
Type of Amputation	Trans Femoral: **4 (22.22%)** Trans Tibial: **13 (72.22%)** Disarticulation:**1 (5.56%)**
Average surgical treatments per patient during the follow up n (range, SD)	**9.9 (2–22; ± 7.4)**
Average Follow U in years n (range, SD)	7.4(3–18; ±4.7)
New Prognostic Classification n (%)	Type IA:**22 (13.10%)** Type IB: **29 (17.26%)** Type IC: **10 (5.95%)** Type IIA: **18 (10.72%)** Type IIB: **21 (12.50%)** Type IIC: **6 (3.58%)** Type IIIA: **8 (4.76%)** Type IIIB: **18 (10.71%)** Type IIIC: **3 (1.79%)** Type IVA: **1 (0.59%)** Type IVB: **7 (4.16%)** Type IVC: **6 (2.98%)** Type VA: **12 (7.14%)** Type VB: **4 (2.38%)** Type VC: **4 (2.38%)**
Fraser's Classification n (%)	Type I: **67 (39.88%)** Type IIA: **56 (33.33%)** Type IIB: **34 (20.24%)** Type IIC: **11 (6.55)**
Ran's Classification n (%)	Type I: **67 (39.88%)** Type IIA: **53 (31.55%)** Type IIB: **36 (21.43%)** Type III A: **5 (2.98%)** Type III B: **7 (4.16%)**

Clinical results and complications of the 3 different classification systems

Table 3 shows clinical results and complications (Karlstrom and Olerud score, Non Union, Mal Union, Infection, Leg Amputation (as last surgery) and Average surgical treatments for each patient during the follow up) correlated to each one of the 3 classification systems (Our new prognostic classification, Fraser's Classification and Ran's Classification).

Prognostic value

The new prognostic classification showed a higher ordinal correlation with KOS score than Fraser's and Ran'sclassification.

Tau B Kendall value was

- 0.853 for new prognostic classification ($p = 0.031$),
- 0,634 for Fraser's classification ($p = 0.34$),
- 0,675 for Ran's classification ($p = 0.26$).

Then for each classification, a multivariate analysis using the multiple regression with backward Wald method was performed to detect factors other than the considered classification to predict KOS.

The analysis results showed that no other factors besides the classifications influenced the KOS score.

Finally, the General Linear Model (GLM), with KOS as the dependent variable and the three classifications as covariates, was performed to compare the prediction strength of each classification, the other two being equal.

Table 3
Clinical results and complications for each 3 classification systems.

Classification	Average objective KOS at 36 months of Follow up (Range; SD)	Patients with Non Union n (%)	Patients with Mal Union n (%)	Patients with Infections n (%)	Patients with Leg Amputation as last surgery n (%)	Average surgical treatments per patient during the follow up n (range, SD)
New Classification Prognostic System	Type IA: 22 excellent Type IB: 16 exellent. 10 goods, 3 acceptable Type IC: 4 excellent, 4 goods, 3 acceptables, 1 poor Type IIA: 9 excellent, 6 goods, 3 acceptable Type IIB: 4 excellent, 10 goods, 3 acceptable, 1 poor Type IIC: 1 excellent, 3 goods, 1 accetable, 1 poors, Type IIIA: 1 excellent, 4 goods, 2 acceptable, 1 poor Type IIIB:2 excellents, 12 goods, 3 accepatble, 1 poor, Type IIIC:1 good, 2 poors Type IVA: 1 good Type IVB: 1 good, 4 acceptables, 2 poor Type IVC: 1 good, 3 acceptables, 2 poor Type VA:2 excellent, 6 goods,4 acceptable Type VB: 1 goods, 2 acceptable, 1 poor Type VC: 1 acceptable, 3 poors	Type IA: 0(0%) Type IB: 1(4.35%) Type IC: 1(4.35%) Type IIA: 1(4.35%) Type IIB: 3 (13.05%) Type IIC: 1(4.35%) Type IIIA: 1(4.35%) Type IIIB: 2(8.70%) Type IIIC: 1(4.35%) Type IVA: 1(4.35%) Type IVB: 3 (13.05%) Type IVC:1(4.35%) Type VA: 2(8.70%) Type VB: 3 (13.05%) Type VC: 2(4.35%)	Type IA:0(0%) Type IB: 1(3.33%) Type IC: 1(3.33%) Type IIA: 2 (6.675%) Type IIB: 3(10%) Type IIC: 1(3.33%) Type IIIA: 1 (3.33%) Type IIIB: 3(10%) Type IIIC: 3(10%) Type IVA: 1 (3.33%) Type IVB: 3(10%) Type IVC: 3(10%) Type VA: 3(10%) Type VB: 3(10%) Type VC: 2 (6.675%)	Type IA: 0(0%) Type IB: 0(0%) Type IC: 1(8.33%) Type IIA: 00(0%) Type IIB: 1(8.33%) Type IIC: 0(0%) Type IIIA: 0(0%) Type IIIB: 1 (8.33%) Type IIIC: 1 (8.33%) Type IVA: 1(8.33%) Type IVB: 2 (16.68%) Type IVC: 1 (8.33%) Type VA: 1(8.33%) Type VB: 2 (16.68%) Type VC: 1(8.33%)	Type IA:0(0%) Type IB:1(5.56) Type IC:2(11.11%) Type IIA:0(0%) Type IIB:2(11.11%) Type IIC:3(16.67%) Type IIIA:0(0%) Type IIIB:2(11.11%) Type IIIC:2(11.11%) Type IVA:0(0%) Type IVB:2(11.11%) Type IVC:2(11.11%) Type VA: 0(0%) Type VB:2(11.11%) Type VC:2(11.11%)	Type IA:3.1(1–6;± 2.9) Type IB:5.7(2–12;± 3.9) Type IC:10.4(2–22;±7.8) Type IIA:6.7(3–11; ±4.6) Type IIB:8.9(3–14; ±6.9) Type IIC:8.3(6–17;±5.6) Type IIIA:9.3(3–18;±7.1) Type IIIB:10.9(8–16; ±7.7) Type IIIC:11.6(8–19; ±7.6) Type IVA:10 Type IVB:13.9(6–21; ±8.4) Type IVC:14.1(2–22; ±12.8) Type VA:7.8(2–22;±7.2) Type VB:12.9(2–22; ±10.6) Type VC: 15.8(2–12;±5.4)
Fraser's Classification	Type I: 28 excellent; 24 good; 10 acceptable, 5 poor Type IIA: 16 excellent; 30 good; 7 acceptable, 3 poor Type IIB: 2 exeecellent, 14 good, 10 acceptable; 7 poor TypeIIC: 3 good; 4 acceptable, 4 poor	Type I:6(26.09%) Type IIA:6(26.09%) Type IIB:8(34.78%) TypeIIC:3(13.04%)	Type I:6(20.00%) Type IIA:9(30%) TypeIIB:10 (33.33%) Type IIC:5 (16.67%)	Type I:3(25.00%) Type IIA:5 (41.67%) Type IIB:3 (25.00%) TypeIIC:1(8.33%)	Type I: 3(16.67%) Type IIA:6(33.33%) Type IIB:8(44.44%) TypeIIC:1(5.56%)	Type I:6.8(2–15;± 4.2) Type IIA 7.4 (2–16; ± 10.8) Type IIB: 12.2 (2–22; ± 10.4) Type IIC: 13.2(10–22; ± 4.2)
Ran's Classification	Type I: 28 excellent; 24 good; 10 acceptable, 5 poor Type IIA:14 execcelents,23 goods; 10 accettable; 6 poor Type IIB: 6 excellents; 9 goods; 11 accettable; 10 poor Type III A: 1 goods; 3 accetable; 1 poor Type III B: 1 goods; 5 accetable, 1 poor	Type I:6(26.09%) Type IIA:3(13.04%) TypeIIB:10 (43.49%) Type III A:2(8.69%) Type III B:2(8.69%)	Type I:6(20.00%) Type IIA:6 (20.00%) Type IIB:8 (26.67%) Type IIIA: 4 (13.33%) Type III B: 6 (20.00%)	Type I:3(25.00%) Type IIA:2 (16.67%) Type IIB:5 (41.67%) Type III A:1 (8.33%) Type III B:1 (8.33%)	Type I:3(16.67) Type IIA:4(22.22%) Type IIB:6(33.33%) Type III A:3(16.67%) Type III B:2(11.11%)	Type I:6.8(2–15; ± 4.2) Type IIA: 7.4 (2–16; ± 10.8) Type IIB: 10.7 (2–22; ± 10.4) Type III A: 10.8(6–22; ± 5.1) Type III B: 13.8(6–22; ± 6.5)

The result was that the new classification was the significant one and had a higher partial eta squared (Prognostic Table 4).

Interobserver agreement

Using the Fraser'S classification system the average K weighted value among the 10 reviewers was 0,61($p = 0.44$); using Ran'sclassification it was 0,68($p = 0.42$) and using the new prognostic classification it was 0,88 ($p = 0.039$). The new prognostic classification showed a significantly higher($p < 0.05$) inter-observer agreement than the other two commonly used (Table 5 *Inter-observer agreement*).

Intra-observer agreement

Using the Fraser'S classification system the average K weighted value was 0,66($p = 0.41$); using the Ran's classification was 0.70($p = 0.30$) and using the new prognostic classification was 0,90 ($p < 0.011$).

The new classification system has a significantly higher intra-observer agreement than the other two classifications ($p < 0.05$).

No differences were found between experienced and unexperienced

Table 4.
Prognostic value of classification systems.

Prognostic Values of the 3 Classification systems		
Classification' System	**Tau B Kendall Value**	**P Value**
Fraser	0.634	$P = 0.34$
Ran	0.675	$P = 0.26$
New Prognostic Classification	0.853	$P = 0.031$

Table 5
Intra-observer agreement.

Intra-observer values of the classification systems		
Classification's System	K of Cohen Value	P value
Fraser	0.66	$P = 0.41$
Ran	0.70	$P = 0.30$
New Prognostic Classification	0.90	$P = 0.011$

observers (Table 6 *Intra-observer agreement*).

Discussion

In the 2020 Karsli B and Tekin SB [12] reported in their paper that the results of floating knee injuries can be affected by the complexity of fracture and condition of soft tissues. Fracture classification 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 McBride and the classification defined by Fraser et al. [6,12,13].

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, Lettsand Vincent and Bohn Durbin classification systems [6,13,14]. 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 an 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 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 [13,14]. Modified Fraser classification system involves patella fracture in floating knee injuries [6]. Although numerous classification systems are available, the clinical results of patients with floating knee injuries are classified according to the Karlstrom–Olerud criteria [15]. In our study, the results of three classification fractures were classified according to the same criteria.

These classifications give accurate information on fracture morphology (it is useful for preoperative planning), they have a fair to moderate interobserver reliability, they provide a good prognostic value according to literature and, least but not last, they are easy. However, they do not provide any evaluation of exposed fractures, soft tissues, ligaments, meniscus etc. that are fundamental for realistic prognostic value and evaluation of future outcomes.

An ideal fracture classification system should be simple, all inclusive, reliable and reproducible. Furthermore, a treatment-oriented classification should provide prognostic information based on the outcome of different fracture patterns, in order to help the surgeon improving preoperative planning and treatment.

When we designed our classification, we asked ourselves:

What makes a good classification?

The first answer we find was: inter-observer reliability. Do different physicians agree on the classification of a particular fracture?

The second answer we find was: Intra-observer Reproducibility. For a given fracture, does the same physician classify it the same way at different times?

Classifications are essential for communication, education, treatment guidelines, and as a prognostic tool. As imaging technology has advanced so have our fracture classifications; the soft tissue can't be ignored and classification systems taking the soft tissue envelope into consideration are essential for creating a complete prognostic picture.

Table 6
Interobserver agreement.

Interobserver values of the 4 classification systems		
Classification's System	K di Cohen Value	P value
Fraser	0.61	$P = 0.44$
Ran	0.68	$P = 0.42$
New Prognostic Classification	0.84	$P = 0.039$

Our alphanumeric classification takes up the major classifications such as OTA-AO and that of periprosthetics Unified Classification System for Periprosthetic Fractures. Because for the traumatologist it is more intuitive to divide the type or association of fracture by distinguishing it with a number and the severity of the total injury by distinguishing it with a letter (the ABC system). In fact, our classification distinguishes flotting knee injuries in 5 macro classifications from extra-articular injuries, to mixed extra-articular and joint injuries, to intra-articular and injuries associated with the patella. In fact, as Ran et al. [6] show us, the patella has a predominant predisposition in the prognostic outcome of floating knee injury.

Instead the letters simplify the myriad of associated soft and noble tissue injuries of the lower extremity by classifying: closed fractures without mention of meniscus ligament injuries (Letters A) soft tissue involvement, closed or open fractures (until GA IIIA) associated breaks meniscal and ligamentous (Letter B), bone loss and subamputated limb (Letter C).

According the paper of Demirtlas et al. [16], adult ipsilateral femur and tibia fractures are severe injuries and adversely affect the quality of life and functional outcomes. The quality-of-life scales should be used along with functional outcome scores in evaluating these injuries. In our study we found that the classification we proposed is better in predicting the final results according to the severity of the fracture and associated injuries according to SF-12.

In "Predictors of outcome of floating knee injuries in adults: 89 patients followed for 2–12 years", Hee et al. [17] constructed a preoperative prognostic scoring scale which showed a sensitivity of 0.72 and a specificity of 0.90 using the outcome of floating knee injuries as fair or poor, according to Karlström and Olerud's criteria. Also they reported an increase in the number of pack years smoked at the time of injury predicted the likelihood of knee stiffness, delays in bony union and full weight bearing ability [17]. Higher injury severity scores were associated with delayed full weight bearing ability [17]. The presence of open fractures predicted the likelihood of knee stiffness and delayed full weight bearing ability. Comminuted fractures were associated with malunion, and segmental fractures with delayed bony union [17]. In our study we found that the classification we proposed is better in predicting the final results according to the severity of the fracture and associated injuries according to Karlstrom and Oulerud.

Moreover, ligamentous knee injuries are among the pathologies accompanying floating knee injuries. Andrade et al. [18] stated that the poor functional result of floating knee injuries was due to the delayed diagnosis of ligamentous knee injuries. We evaluated ligamentous knee injuries in our study, and we do know their effect on the results, which may be described as one of the limitations of our study. Infact in the study of Blaker CL et al. [19] reported the rupture of the anterior cruciate ligament (ACL) is a well-known risk factor for the development of posttraumatic osteoarthritis (PTOA), but patients with the "same injury" can have vastly different trajectories for the onset and progression of disease. Minor subcritical injuries preceding the critical injury event may drive this disparity through preexisting tissue pathologies and sensory changes. Subcritical knee injury produced focal osteochondral lesions in the patellofemoral and lateral tibiofemoral compartments with no resolution for the duration of the study (8 weeks). These lesions were characterized by focal loss of proteoglycan staining, cartilage structural change, chondrocyte pathology, microcracks, and osteocyte cell loss. Injury also resulted in the rapid onset of allodynia (at 1 week), which persisted over time and reduced ACL failure load, accompanied by evidence of ACL remodeling at the femoral enthesis [20].

In 2009, Rothnam et al. [21] reported an high complication rates accompany floating knee injuries. The associated injuries were quite frequent with the floating knee. Some of the associated injuries caused a delay in surgical management and post-operative rehabilitation. In assessment of the final outcome, patients with associated knee and vascular injuries had a poor prognosis. Majority of the patients with associated injuries had a good or excellent outcome.

In our study, we found that the classification we proposed is better in predicting the total impact that type of floating can affect the patient's quality of life based on the severity of the fracture and associated injuries.

Our study had several limitations. First, the study data were collected retrospectively. 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

Based on the data obtained, we observed that the fluctuating knee injuries that we could classify led to different clinical outcomes based on the classification. In conclusion, we believe that our classification is the best at the moment because it includes and differentiates the floating kne typology not only from a bone point of view but also from a ligamentous and neurovascular point of view.

Human and animal right

For this type of study is not required any statement relating to studies on humans and animals. All patients gave the informed consent prior being included into the study. All procedures involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments. This paper did not need the ethical committee's approval.

CRediT authorship contribution statement

Luigi Meccariello: Conceptualization, Writing – original draft, Writing – review & editing. **Roberta Pica:** Conceptualization, Writing – original draft. **Rocco Erasmo:** Formal analysis, Methodology, Writing – original draft. **Mario Ronga:** Data curation, Investigation, Methodology. **Francesco Ippolito:** Conceptualization, Writing – original draft, Writing – review & editing. **Giovanni Vicenti:** Data curation, Formal analysis, Writing – original draft. **Giuseppe Maccagnano:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Michele Coviello:** Conceptualization, Investigation, Methodology. **Francesco Liuzza:** Conceptualization, Investigation, Methodology. **Giuseppe Rollo:** Conceptualization, Writing – original draft, Writing – review & editing. **Massimiliano Carrozzo:** Formal analysis, Methodology, Writing – original draft. **Giuseppe Rovere:** Data curation, Investigation, Writing – original draft. **Giuseppe Rinonapoli:** Conceptualization, Methodology, Writing – original draft. **Luigi Matera:** Conceptualization, Writing – original draft. **Gaetano Bruno:** Investigation, Methodology. **Lorenzo Scialpi:** Writing – original draft, Writing – review & editing. **Predrag Grubor:** Conceptualization, Formal analysis. **Federico Bove:** Conceptualization, Methodology. **Vincenzo Caiaffa:** Supervision.

Declaration of competing interest

All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

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