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Surgical treatment of type II floating knee: comparisons of the results of type IIA and type IIB floating knee

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Abstract The prognosis of type II floating knee injuries was not as good as that of type I. Our purpose is to clarify the factors affecting the outcome of type II floating knee injuries. Thirty-five patients (36 limbs) with type II floating knee injury were studied with a mean follow-up of 52 months (26–96). Blake and McBryde had classified these injuries into type I for pure diaphyseal (true type) fracture and type II if the intra-articular involvements are one or more including hip, knee and ankle joints (variant type). According to this classification, we divided these patients into two groups depending on whether their knees were involved or not. Those cases with intra-articular knee involvement were classified as type IIA, while those without intra-articular knee involvement were classified as type IIB. Of the 36 cases, 21 were classified as type IIA and 15 were type IIB. The functional outcomes of these injuries were evaluated by using the criteria of Karlström and Olerud and analyzed with multivariate analysis. After multivariate analysis with logistic regression, we show the following results: first, the poor functional outcome of type II floating knee is contributed by type IIA. Second, the type IIA group has severer femoral open fracture grading ($P = 0.027$) and poorer functional outcome ($P = 0.009$) than type IIB. Third, the significant contributing factors to final outcome are the group ($P = 0.013$) and the fixation time after injury in femur ($P = 0.015$). Intra-articular knee involvement is the most important factor contributing to poor outcome of type II floating knee. The treatment of floating knee injuries with intra-articular knee involvement is

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still difficult. Further efforts to search better methods of treatment are required for these complex injuries in the future.

Keywords Floating knee · Multivariate analysis · Intra-articular knee involvement

Introduction

Floating knees, ipsilateral fractures of the femur and tibia, may have combinations of diaphyseal, metaphyseal and intraarticular fractures. Blake and McBryde had classified these injuries into type I for pure diaphyseal (true type) fracture and type II if the intra-articular involvements were one or more including hip, knee and ankle joints (variant type) [6]. Because these are caused by high-energy trauma, they are associated with potentially life-threatening injuries of the head, chest and abdomen [15]. Complications attributed to floating knee injuries are infection, excessive blood loss, fat embolism, malunion, delayed or nonunion, knee stiffness, prolonged hospitalization and inability to bear weight [7, 15]. By using the criteria of Karlström and Olerud [13], most published series reported more than 65% of the results to be excellent and good in the cases of floating knee, such as 86% by Karlström and Olerud [13], 72% by Veith et al. [15], 81% by Anastopoulos et al. [2] and 65% by Gregory et al. [8]. Those results were much better than 29% conservatively reported by Fraser et al. [7]. Recent reports show that surgical stabilization of both fractures and early mobilization can avoid most complications and achieve the best clinical results [2, 5, 8, 11, 13, 14], but this statement is only true to type I injuries. Little attention has been paid to the type II injuries. In some series, poorer results are found when one or both fractures are intraarticular than when both are diaphyseal [1, 12]. In our experience, the functional outcome of type II floating knee is poorer than that of type I. Although we can avoid most of the complications by operative treatment in type II floating knee injuries, the satisfactory results are still difficult to be achieved. Because we found different results between the type IIA and type IIB floating knee injuries; we used statistic analysis to evaluate the significant factors affecting the functional prognosis in type II floating knee injuries.

Materials and methods

We retrospectively reviewed all patients (41) with type II floating treated at Kaohsiung Medical University Hospital in Taiwan from January 1992 to December 1996. Because 6 patients were lost to follow-up, 35 patients with 36 type II floating knees were available for analysis (Table 1). Their age distribution ranged from 15 to 66 with a mean of 38 years, including 26 males and 10 females. Thirty-four cases (94%) of these fractures were caused by road accidents, while one is caused by heavy-material crushing and the other suffered from falling.

According to the classification of Blake and McBryde [6], we divided these patients into two groups depending on whether there were intra-articular knee involvement or not (Fig. 1). Those cases with intra-articular knee involvement were classified as type IIA; on the contrary, those only with intra-articular hip or ankle involvement without intra-articular knee involvement were classified as type IIB. Of the 36 cases, 21 were classified as type IIA (cases 1–21) and 15 were type IIB (cases 22–36). One case with both knee and ankle injuries and one case with all three joints injuries were classified as type IIA.

Out of the 36 fractures of the femur, 19 were closed (52.8%) and 17 were open (3 grade I, 7 grade II, 6 grade IIIA, 1 grade IIIB) according to the criteria of Gustilo et al. [9]. There were 23 closed tibial fractures (63.9%) and 13 open tibial fractures (2 grade I, 5 grade II, 4 grade IIIA, 2 grade IIIB). Twenty cases (55.6%) had open fractures in at least one fracture; 66.7% in the type IIA group and 40% in the type IIB group were open fractures.

The mean injury severity sore (ISS) [3] of the 36 cases was 18 (range 9–34). Significant associated injury was noted in 18 cases (50%). There were 9 craniocerebral injuries, 12 other fractures, 1 chest injury and 2 significant soft tissue injuries. There were 47.6 and 53.3% of associated injuries in type IIA and IIB group, respectively. One patient received emergent craniotomy for evacuation of an intracranial hematoma. There was no major vascular injury.

On admission, all patients were carefully evaluated to detect and manage the life-threatening conditions under traction or temporary fixation of injured limbs. When a fracture was open, a sterile dressing was applied, and the patient was given tetanus and antibiotic prophylaxis. Once the vital function was stable, the open fracture was thoroughly debrided in the operative room. Debridements were performed in all open fractures within 12 h after injury. The number of cases receiving ORIF delayed over 1 week was 11 and 15 in tibia and femur, respectively.

The results were evaluated according to the criteria established by Karlström and Olerud [13] (Table 2).

Table 1 Patient data

Patient	Age/sex	Mechanism of injuries	Associated injuries/ ISS	Fixation time (days) delay F/T	Femur fracture	Femur treatment	Tibia fracture	Tibia treatment	Follow-up (months)	Complications	Outcome
1	50/M	MVC	No/16	1/1	Closed segmental diaphyseal	Plate	Closed plateau	Plate	26	None	Poor
2	24/M	Pedestrian	Yes/18	14/14	Closed segmental diaphyseal	Plate	Open II plateau and diaphyseal	Plate	42	Infection of tibia and re-fracture of femur	Poor
3	66/F	MVC	Yes/10	0/0	Closed diaphyseal	Plate	Closed plateau	Screws	33	None	Acceptable
4	15/M	MVC	Yes/20	0/0	Closed diaphyseal	Plate	Closed plateau	Screws	87	None	Excellent
5	54/M	Crushing	Yes/20	13/13	Closed diaphyseal	Plate	Closed plateau	Plate	80	None	Acceptable
6	24/M	MCC	No/9	3/3	Closed diaphyseal	Interlocking IM nail	Closed plateau and diaphyseal	Plate	32	None	Good
7	48/F	MCC	No/17	0/0	Open I diaphyseal	Interlocking IM nail	Open I plateau	Plate	36	None	Acceptable
8	42/M	Pedestrian	Yes/34	15/15	Closed diaphyseal	Plate	Closed plateau	Plate	67	Peronael n palsy	Good
9	18/M	MCC	Yes/26	28/0	Open II segmental diaphyseal	Plate	Closed plateau	Cast	46	LLD>3cm, malunion	Poor
10	20/F	MVC	No/17	8/8	Open II supracondylar intercondylar	Pin + cast	Closed diaphyseal	Plate	74	Nonunion of femur	Acceptable
11	37/M	MVC	No/17	5/5	Open I supracondylar intercondylar	Buttress plate	Open I diaphyseal	Interlocking IM nail	60	None	Good
12	40/M	MVC	No/20	7/7	Open IIIA supracondylar intercondylar	Dynamic condylar screw	Open IIIA diaphyseal	Plate	72	None	Acceptable
13	16/F	MVC	Yes/20	9/9	Open IIIA supracondylar intercondylar	L-condylar plate	Closed plateau	Buttress plate	46	None	Good
14	64/M	MVC	Yes/20	0/0	Open IIIA supracondylar intercondylar	External fixator	Closed diaphyseal	BKA	58	Nonunion-plate, BKA	Poor
15	54/M	MVC	No/17	20/20	Open IIIA supracondylar intercondylar	L-condylar plate	Open II diaphyseal	Plate	67	None	Poor
16	30/M	MVC	No/20	0/0	Open II supracondylar intercondylar	Dual buttress plates	Open IIIA diaphyseal + Closed Pilon	Plate + External fixator	79	None	Poor
17	56/F	VC	No/20	11/11	Open IIIA supracondylar intercondylar	L-condylar plate	Open IIIA diaphyseal	Buttress plate	68	None	Poor

Table 1 continued

Patient	Age/sex	Mechanism of injuries	Associated injuries/ ISS	Fixation time (days) delay F/T	Femur fracture	Femur treatment	Tibia fracture	Tibia treatment	Follow-up (months)	Complications	Outcome
18	52/M	MVC	No/20	4/4	Open IIIA supracondylar intercondylar + Neck	Buttress plate + DHS	Open IIIB diaphyseal + open II ankle	External fixator	82	LLD>3cm, malunion	Poor
19	30/F	MVC	Yes/17	0/0	Open II supracondylar intercondylar	Plate	Closed plateau	Buttress plate	52	Infection of tibia	Poor
20	59/F	VC	No/20	0/0	Open IIIB supracondylar intercondylar	AKA	Open II diaphyseal	Nil	29	AKA	Poor
21	31/M	MVC	Yes/16	0/0	Closed lateral condylar	Dynamic condylar screw	Closed diaphyseal + ankle	Plate + screw	0	Expire	Poor
22	32/M	VC	Yes/25	14/0	Closed diaphyseal	Interlocking IM nail	Closed Pilon	Cast	61	None	Poor
23	32/M	VC	Yes/25	14/0	Closed segmental diaphyseal	Interlocking IM nail	Closed Pilon	Cast	61	None	Poor
24	29/M	MVC	Yes/17	4/4	Closed diaphyseal	Interlocking IM nail	Closed ankle	Plate + Screws	48	None	Good
25	41/M	MVC	No/17	10/10	Open II diaphyseal	Interlocking IM nail	Closed diaphyseal + ankle	Interlocking IM nail + cast	54	None	Acceptable
26	33/F	VC	Yes/16	3/3	Closed diaphyseal + neck	Screw + Plate	Closed ankle	Plate + screws	74	None	Good
27	28/M	MVC	Yes/16	10/0	Open I Winquist type II	L-condylar	Closed ankle	Cast	40	None	Good
28	38/F	MVC	No/9	0/3	Closed femoral neck	Screws	Closed diaphyseal	Plate	54	None	Good
29	36/M	MVC	No/17	10/10	Closed femoral neck and Segmental	Screws and interlocking IM nail	Open II diaphyseal	Interlocking IM nail	29	Tibial infection and nonunion	Acceptable
30	35/M	MVC	No/20	13/48	Open II diaphyseal	Plate	Open IIIA diaphyseal + Closed Pilon	Plate + screws	47	None	Good
31	24/M	MVC	Yes/25	15/0	Closed diaphyseal	Plate	Closed ankle	Splint	59	None	Acceptable
32	61/F	MVC	Yes/13	7/7	Closed diaphyseal	Plate	Closed ankle	Screws	20	None	Good
33	34/M	MVC	Yes/20	5/5	Closed femoral neck and diaphyseal	DHS + Plate	Open IIIb ankle	Plate + Screws	26	None	Good
34	20/M	MVC	No/16	0/0	Closed diaphyseal	Plate	Closed diaphyseal + ankle	Plate	33	None	Excellent

Table 1 continued

Patient	Age/sex	Mechanism of injuries	Associated injuries/ ISS	Fixation time (days) delay F/T	Femur fracture	Femur treatment	Tibia fracture	Tibia treatment	Follow-up (months)	Complications	Outcome
35	39/M	MVC	No/9	7/17	Open II diaphyseal I	Plate	Open II diaphyseal + ankle	Plate + Screws	71	None	Good
36	62/M	Fall	No/9	5/0	Closed trochanter and diaphyseal	DHS + Plate	Closed ankle + Pilon	Screw + wire	57	None	Good

F/T femur/tibia, *MVC* motor vehicle crash, *VC* vehicle crash, *MCC* motor crash, *BKA* below-knee amputation, *DHS* dynamic hip screw, *AKA* above-knee amputation, *IM* intramedullary; *LLD* leg-length discrepancy

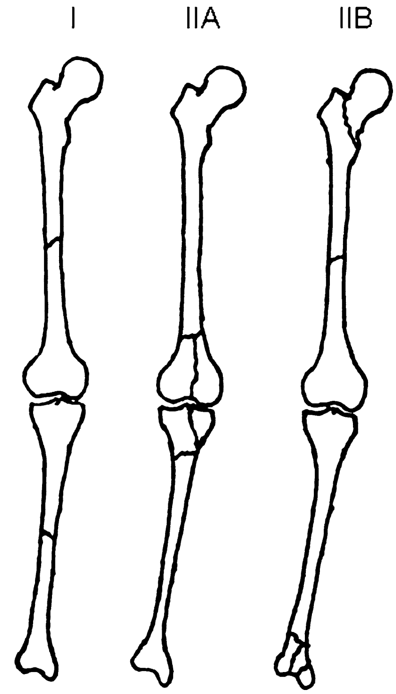

Fig. 1 Sketch of floating knee classification**.** According to the classification of Blake and McBryde, the floating knees are classified as type I for pure diaphyseal fracture and type II if the intra-articular involvements are one or more including hip, knee and ankle joints. Type II fractures are sub-classified if those cases with intra-articular knee involvement as type IIA, while those without intra-articular knee involvement as type IIB

Statistical analysis

Our purpose is to find the differences within the fracture type group and factors contributing to functional outcome result. The multivariate analysis was used in this study. In addition to variables of the floating knee type (type IIA or type IIB) and the functional outcome (the criteria of Karlström and Olerud [13]), we selected other five variables to analyze: age at trauma, gender, open fracture grading in the femur and the tibia, ISS and fixation time after injury in the femur and the tibia. These factors are preoperative variables that might have effected the final clinical outcome. Because the treatment methods for both the femoral and tibial fractures were complicated, these factors were deleted from this analysis.

We use ANOVA to analyze the significant differences of variables between groups. Then we analyze the contribution of variables to functional outcome by logistic regression analysis. The dependent variable was functional outcome. We defined satisfactory (S) outcomes as those patients with excellent or good results and unsatisfactory (US) outcomes as those patients with acceptable or poor results. The S outcome

Table 2 Criteria established by Karlström and Olerud

Criteria	Excellent	Good	Acceptable	Poor
Subjective symptoms from thigh or leg	0	Intermittent slight symptoms	More severe symptoms, impairing function	Considerable functional impairment; pain at rest
Subjective symptoms from knee or ankle	0	Same as above	Same as above	Same as above
Walking stability	Unimpaired	Same as above	Walking distance restricted	Uses cane, crutch, or other support
Work and sport	Same as before accident	Given up some sport; work same as before accident	Change to less strenuous work	Permanent disability
Angulation, rotational deformity, or both	0	<10°	10 to 20°	>20°
Shortening	0	<1 cm	1 to 3 cm	>3 cm
Restricted joint mobility (hip, knee or ankle)	0	<10° at ankle; <20° at hip, knee, or both	10 to 20° at ankle; 20 to 40° at hip, knee, or both	>20° at ankle, >40° at hip, knee, or both

Table 3 Allotment of dummy variables in each predictor

Dependent variables	Item Functional outcome	Allotment of dummy variables Satisfactory: 0; unsatisfactory: 1
Explanatory variables (predictors)	Gender	Female: 0; male: 1
	Age	<38:0; >38:1
	ISS	<18:0; >18:1
	Floating knee type	Type IIB: 0; type IIA: 1
	Open fracture grading	Closed, GI, GII: 0; GIII: 1
	Fixation time	<1 week: 0; >1 week: 1

and US outcome were allotted to dummy variables '0' and '1' respectively. The other allotments of dummy variables are summarized in Table 3. A personal computer with statistical analysis software (SPSS 12.0 v for Windows) was used to do above analyses. The odds ratios (ORs) for individual predictors of the functional outcomes were calculated, and a value of $P < 0.05$ was considered significant.

Results

The average length of follow-up is 52 months ranging from 26 to 96 months. The average hospitalization was 40 days (1–152). There were two femoral fractures (cases 11 and 14) and three tibia fractures (cases 11, 18 and 29) that required more than 1 year to union. There were three nonunions, one occurred in the tibia (case 29) and two in the femur (cases 10 and 14). Case 29 suffered from tibia infective nonunion. At the end of follow-up, he had a union of tibia finally after debridement and bone graft. Case 14 received re-operation after nonunion for 10 months. After osteosynthesis with L-condylar plate and bone grafting, union was achieved 7 months later. The other (case 10) refused further operative treatment.

The functional outcomes by using the criteria of Karlström and Oleud were 2 excellent results (5.6%), 13 good (36.1%), 8 fair (22.2%) and 13 poor (36.1%). Among them, there were 1 excellent (4.8%), 4 good (19%), 5 acceptable (23.8%) and 11 poor (52.4%) results in type IIA group. However, there were 1 excellent (6.6%), 9 good (60%), 3 acceptable (20%) and 2 poor (13.3%) results in type IIB group. Only one patient with bilateral floating knee (cases 22 and 23) had poor result. The comparisons of patient data and functional outcomes between the groups of type IIA and IIB floating knee were summarized in Tables 4 and 5.

Complications occurred in 10 patients (Table 6). Most were in the type IIA group. One patient died from fat embolism on the day after the operation. Two patients received amputation. One received below-knee amputation because of a severe foot injury, and the other was treated with above-knee amputation because of combined grade IIIB open femoral fracture and grade II open tibial fracture. Both amputations were performed within 24 h after injury. Three patients (8.3%) suffered from deep infections. All infections occurred in tibial fractures: two were open and the other was closed. One patient (2.8%) with a segmented femoral fracture had implant (plate) failure during

Table 4 Summary of patient data and comparison between different groups

	Cases		Age	#day	Associated injuries	Open fractures			Complication	
	Male	Female				Total	Femur	Tibia	Total	Infection
Type IIA (21)	14	7	39.5	35	10 (47.6%)	14 (66.7%)	13 (61.9%)	9 (42.9%)	9 (42.9%)	2 (9.5%)
Type IIB (15)	12	3	36.3	46	8 (53.3%)	6 (40%)	4 (26.7%)	4 (26.7%)	1 (6.7%)	1 (6.7%)
Total (36)	26	10	38.2	39.8	18 (50%)	20 (55.6%)	17 (47.2%)	13 (36.1%)	10 (27.8%)	3 (8.3%)

Age averaged age; #*day* averaged days of hospitalization

Table 5 Numbers of functional result in different group of type II floating knee

Functional result	Type	
	II A	II B
Excellent	1	1
Good	4	9
Acceptable	5	3
Poor	11	2
Total	21	15

admission. Re-ORIF was performed at that time. There were two patients (5.6%) with malunion and late leg length discrepancy of more than 3 cm. One patient had peroneal nerve palsy after operation and recovered 4 months later.

The result of multivariate analysis for the difference within fracture type is in Table 6. There are significant differences on functional outcome ($P = 0.009$) and femoral open fracture grading ($P = 0.027$) between type IIA and IIB groups. The type IIA group has severer femoral open fracture grading and poorer functional outcome than type IIB. This implicates that the poorer outcome of type IIA may be contributed by severer femoral open fracture.

Logistic regression was done to determine predictors of outcome. Accordingly, the predictive logistic regression equation was as follows:

Log 1-p/p = –2.99 + 3.254 group + 0.465 severity of open fracture injury in the femur + 2.13 severity of open fracture in the tibia + 5.174 fixation time after injury in the femur – 3.615 fixation time after injury in the tibia + 1.664 Age + 0.437 Sex – 1.781 ISS ($P = 0.014$).

Among the variables, group ($P = 0.013$) and fixation time after injury in femur ($P = 0.015$) were significantly related to the final result (Table 7). The model predicts 86.1% of the responses correctly (a sensitivity of 0.73 and a specificity of 0.95).

Discussion

We agree the viewpoint of Yokoyoma et al. [16, 17] that the criteria of Karlström and Olerud include some problems. The criteria is not a point system which can be used to quantify the respective factors. The most disadvantageous is that only one factor poor will yield a poor result, so the functional outcome has a dangerous possibility of being poor. This evaluation system may have some shortcomings, but no other consenting methods have been developed in evaluating functional result of the floating knee injuries. Recent reports using multivariate analysis to clarify those factors affecting the floating knee injuries were also according to the Karlström's criteria [10, 16, 17]. A system of preoperative prognostic scoring scale developed by Hee et al. [10] was also based on the criteria of Karlström and Olerud [13]. So, we also used these criteria including age, gender, injury severity score, presence of

Table 6 Complication

Complication	IIA	IIB
Infection	2	1
Implant failure	1	0
Nonunion	2	1
Malunion	2	0
Leg length discrepancy (>3 cm)	2	0
Peroneal nerve palsy	1	0
Amputation	2	0
Died	1	0
Total	9 (13 in 9 patients)	1(2 in 1 patient)

Table 7 ANOVA analysis for the difference of variables between fracture type

	P value
Functional outcome	0.009
Gender	0.768
Age	0.517
ISS	0.306
Open fracture grading of femur	0.027
Open fracture grading of tibia	0.492
Fixation time after injury in femur	0.610
Fixation time after injury in tibia	0.549

Table 8 Regression coefficients and odds ratios (OR) for all predictors by logistic regression

	Regression coefficients	Significance (*P* value)	Odds ratio
Floating knee type (group)	3.254	.013	25.896
Gender	0.437	0.686	1.548
Age	1.664	0.151	5.283
ISS	–1.781	0.193	0.168
Open fracture grading of femur	0.465	0.773	1.593
Open fracture grading of tibia	2.130	.222	8.417
Fixation time after injury in femur	5.174	0.015	176.602
Fixation time after injury in tibia	–3.615	0.060	0.027
Constant	–2.990	0.044	0.050

intraarticular fractures, fixation time after injury and presence of open fractures to elucidate the outcome of our cases.

It is clear that aggressive operation, to achieve rigid fixation and early mobilization, can yield more satisfactory results than nonoperative treatment in floating knee injury. Because all aforementioned series focused on type I floating knee, only few of type II floating knee cases were included; previous statement is only true for type I floating knee injuries. If we focus on type II floating knee, we will find that the result of treating type II floating knee is unsatisfied. In a series of type II floating knee (type IIA) of Adamson et al. [1], 24% of the results were good and excellent. We also achieved only 41.7% of excellent and good results in type II floating knee. In our experience, the outcome of the cases in type I floating knee was better (76.6% of good and excellent results) [12], while the outcome of the cases in type II was comparatively poor. Recent reports, using multivariate analysis, also claim that the outcome of type II floating knee is poorer than that of type I [10, 16, 17]. In this article, we have focused on the type II floating and analyzed the reasons of poor result.

After dividing type II floating knee into types IIA and IIB, we obtained 23.8 and 61.5% from good to excellent results in type IIA and IIB groups, respectively. Obviously, the result of the cases in type IIA group is poorer than that in type IIB. The poor results in type II floating knee might be mostly due to the poor result in type IIA. The outcome of type IIB floating knee in our series is similar to that of type I. Why the result of the cases of type IIA floating knee is poorer than that of type IIB?

After analyzing the variables between type IIA and type IIB in our series, we found that the outcome and femoral open fracture grading were significant differences between type IIA and type IIB. This implicates that the severer femoral open fracture grading in type IIA group may be the reason for poorer outcome. Yokoyoma et al. [16, 17] also mentioned that severity of damage to the knee joint and open injuries in the thigh were found to be significant factors contributing to the functional outcome in floating knee injuries. Using logistic regression to find the factors contributing to functional outcomes, we could not find the severity of open fracture in the femur had significant contribution to functional outcome (OR = 1.593; $P = 0.773$; Table 8). The significant contributing factors to functional outcome are the group and the time delay in femoral fixation. These data show that the most significant contributing factor to final outcome is group (knee involvement). Although the severity of open fracture in the femur is significantly different between groups, it may not significantly contribute to functional outcome.

In early series, some reports have mentioned that articular involvement, especially knee joint, has poor functional results [4, 7]. The two recent studies about the knee involvement of floating knee present the same viewpoint: floating knee with intra-articular knee joint involvement hampers knee movement and has poor result. With multivariate analysis, some series [16, 17] reported that significant contributing factors affecting the final outcome of floating knee injuries were intra-articular involvement of the knee joint.

After the multivariate analysis according to the criteria of Karlström and Olerud [13], we clearly showed that intra-articular knee involvement was the most important factor contributing to poor outcome of type II floating knee. In most of our patients, the intra-operative findings revealed intact cruciated ligaments and meniscus. We think the poor outcome of type II floating knee comes from articular injury and stiffness of knee joint after prolong protection.

According to recent reports and our experience, aggressive operative treatment can achieve a very good result on floating knee injuries except type IIA. The treatment of floating knee injuries with knee involvement is still difficult.

The main drawback of our study is that this is the only retrospective study without control group. Due to the few numbers of patients with severe associated injuries, it is not easy for us to perform a prospectively randomized control study. Further efforts to search better methods of treatment are required for these complex injuries in the future.

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