A. J. Dwyer · R. Paul · M. K. Mam · A. Kumar ·
R. A. Gosselin

Floating knee injuries: long-term results of four treatment methods

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Abstract One hundred twenty-four consecutive patients with true floating knee injury presented between 1987 and 2001. They were treated with non-operative, operative (external fixation and intramedullary nailing) and combined modalities. Sixty patients were followed up, at an average of 7.2 years, for age, gender, type of trauma and fracture; time to fracture union and time to mobilisation. Complications that were encountered and return to normal activities were recorded. Better and comparable union rates of fractures, earlier return to activities and higher excellent and good long-term functional results were observed among combined and operative (intramedullary nail) groups. Using combined modalities of treatment is an affordable, practicable and effective approach, especially for a resource-poor environment. External fixation of the fractured femur resulted in a decreased range of movement at the knee due to quadriceps muscle fixation. Fractured tibia, treated by any of the method, did not interfere with patient's joint mobilisation whereas associated injuries did.

Résumé Cent vingt-quatre malades consécutifs ont présenté un genou flottant traumatique entre 1987 et 2001. Ils ont été traités avec une méthode non—opératoire, une méthode opératoire (fixation externe et enclouage centromédullaire) et une méthode à modalités combinées. Soixante malades ont été suivis pendant une moyenne de 7,2 années en notant l'âge, le genre, le type de trauma et de fracture, la durée de consolidation osseuse, le délai de début

de mobilisation, les complications rencontrées et le retour aux activités normales. Parmi les groupes combinés et opératoires (enclouage centromédullaire) ont été observés une meilleure vitesse de consolidation des fractures, une reprise d'activité plus rapide et plus de bons ou très bons résultats fonctionnels. La modalité combinée est une approche accessible et efficace pour un environnement aux ressources limitées. La fixation externe du fémur fracturé a entraîné une diminution de la mobilité du genou à cause de la fixation du quadriceps. La fracture du tibia, quelque soit son traitement, n'interfère pas avec la mobilisation articulaire à la différence des lésions associées

Introduction

At present, operative treatment is considered to be optimal for ipsilateral fractures of the femur and tibia [13], with intramedullary nailing of the femur the key to management [2, 7, 16]. In certain areas of developing countries, the modality of treatment must be guided by the available resources and hence the options, and eventual functional outcome may vary. We have treated this injury over the past 14 years in a relatively resource-poor environment and have attempted to analyse the best modality of treatment in terms of long-term results and functional outcome.

Material and methods

One hundred twenty-four patients with ipsilateral fracture of the femur and tibia presented between 1987 and 2001. Seven died within 24 h of admission, 34 were treated by amputation, six had inadequate records, and 17 were lost to follow-up. Sixty patients with “true floating knees”, Fraser [6] type I fractures, that exclude intra-articular fractures of the tibia and femur, were studied with an average follow-up of 7.2 (range 3–11) years. Patients with penetrating, periprosthetic, pathological, intra-articular or previous femoral fractures were excluded. All patients with previous knee injuries and previous knee surgery were also excluded.

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A. J. Dwyer (✉) · R. Paul · M. K. Mam · A. Kumar
Department of Orthopaedic Surgery,
Christian Medical College and Hospital,
Ludhiana, Panjab, 141008, India
e-mail: amitabhdwyer@yahoo.com
Tel.: +91-161-5024054
Fax: +91-161-2609958

R. A. Gosselin
School of Public Health,
University of California–Berkeley,
Berkeley, CA, USA

Fractures were then classified as per Bansal's radiological criteria [3] for the site of fracture. In group 1, there were 45 fractures affecting the shaft, with none being juxta-articular, i.e. they did not involve the condylar flare of the respective bones. In group 2, one fracture was juxta-articular; there were eight cases in group 2A, in which the femoral fracture involved the condylar flare, and four in group 2B, in which the tibial fracture involved the condylar flare. There were three in group 3, in which both fractures were juxta-articular. The treatment chosen by the consultant in charge was dictated by the type of injury and options available. A hinged plaster-cast brace was applied for closed and grade 1 open fractures within 72 h of admission (depending on medical condition of the patient) and the brace was re-applied at 6-weekly intervals until fracture consolidation. All patients treated with operative modalities (external fixation or intramedullary nailing) were taken to the operation theatre within a week of admission, and after thorough debridement of any open wounds the operative treatment was performed. External fixation was removed when bridging callus was observed radiographically, and the limb was protected in a functional brace until the fracture consolidated. Clinical union was defined as the ability to perform single-leg standing on the injured limb without pain or instability. Radiographic union was defined as three bridging cortices seen on the combined antero-posterior (AP) and lateral views. Failure to unite with no signs of progression of union after 9 months from the injury was regarded as non-union. For final functional assessment, the results were analysed using criteria described by Karlstrom and Olerud [12]. Statistical analysis was done using the non-paired *t* test for continuous variables, setting statistical significance at $p < 0.05$.

Results

Patient ages ranged from 13 to 49 (average 26.8) years, with most (26/60) in the age group of 21 to 30 years. There were 54 men and six women. Most injuries (57/60) occurred following high-energy road-traffic accidents, and 43/60 involved motorcyclists or motor scooter riders (Table 1). Most femoral fractures (42/60) were closed

Fig. 1 Associated injuries in 60 patients with floating knee injury

whereas the majority of tibial fractures (38/60) were open. Thirty-five fractures involved the right extremity, and 25 involved the left extremity. Forty patients had associated injuries (Fig. 1), and results of various modalities of treatment are presented in Table 2.

Non-operative treatment Twelve patients were treated by closed reduction with or without transfixing pins incorporated in the hinged functional brace. Eleven femoral fractures were closed while one was a Gustilo [8] grade 1 open fracture. Eight tibial fractures were closed, and four were Gustilo grade 1 open fractures. Fewer surgical procedures (average 1.8) were the only major advantage with this modality (Table 2). Associated injuries to the upper limbs delayed walking with aid (average 5.3 weeks). No patient had an extension lag. Delayed union of 28, 30 and 40 weeks, respectively, was observed in three femoral fractures and in three tibial fractures, which united at 40, 44 and 46 weeks, respectively, without further surgical intervention. Two patients had 15° of varus deformity of the femur and shortening of 2 cm of the affected limb. All other fractures united with angulation of <8°. As per the criteria of Karlstrom and Olerud [12], eight patients had excellent to good results while three were acceptable and one patient had poor results. (Table 3).

Combined treatment Eleven patients were treated with intramedullary nailing of the femur and closed reduction and functional cast bracing of the tibia. There were nine closed and two open Gustilo [9] grade 3A femoral fractures, and six closed and five open Gustilo grade 3A tibial fractures. These patients benefited from a maximum range of dorsi-flexion and plantar flexion at the ankle and spent relatively less time (average 27 days) in hospital (Table 2). Four patients had delayed union of the femur: one united at 25 weeks while the other three united at 28 weeks without additional surgical intervention. One patient had delayed union of the tibia that required Phemister bone grafting and united at 44 weeks. A gap non-union of the tibia was treated by distraction histogenesis, and the fracture united at 80 weeks. Eight patients had excellent to good results while one had acceptable and two poor results (Table 3).

Table 1 Mode of injury and gender distribution

Mode of injury	Male	Female	Total
Road traffic accidents			
a. Motorcyclists	43	—	43
b. Pedestrians	8	6	14
High-energy moving machines			
a. Machine belt injury	2	—	2
b. Fall in tube well	1	—	1
Total	54	6	60

Table 2 Observations of various modalities of treatment

	Conservative	Combined	Operative intramedullary nail	Operative external fixation
Number of patients	12	10 (1 tibial gap non-union excluded)	20 (3 tibial non-unions excluded)	14
Hospital stay	31.3 days Range 10–79 days	27.0 days Range 13–45 days	28.1 days Range 14–45 days	26.6 days Range 14–45 days
Femur union in weeks	23.2 weeks Range 16–40 weeks	20.6 weeks Range 12–28 weeks	19.4 weeks Range 12–28 weeks	22.2 weeks Range 12–36 weeks
Tibia union in weeks	27.5 weeks Range 12–46 weeks	24.4 weeks Range 12–44 weeks	23.8 weeks Range 16–42 weeks	26.0 weeks Range 12–42 weeks
Walk with aid	5.3 weeks Range 1.5–10 weeks	5.0 weeks Range 1–15 weeks	4.2 weeks Range 1–20 weeks	4.5 weeks Range 1–18 weeks
Return to activity	9.5 months Range 5–18 months	8.1 months Range 3–15 months	6.8 months Range 5–18 months	8.4 months Range 6–16 months
Number of surgical procedures	1.8 Range 1–3	2.7 Range 1–5	2.9 Range 1–6	3.2 Range 2–5
Range of motion at knee	116.7° Range 0°–135°	130.5° Range 0°–135°	121.3° Range 0°–135°	90.0° Range 0°–135°
Range of dorsi-flexion at ankle	11.3° Range 0°–15°	13.6° Range 0°–15°	12.5° Range 0°–15°	12.1° Range 0°–15°
Range of plantar-flexion at ankle	25.0° Range 0°–30°	27.3° Range 0°–30°	26.0° Range 0°–30°	26.3° Range 0°–30°

Operative treatment

Intramedullary nailing: Intramedullary interlocking nails (15) and Kuntscher nails (eight) were used to stabilise 15 closed, five Gustilo grade 3A and three Gustilo grade 3B open femoral fractures that united at an average 19.4 weeks. The patients were mobilised at the earliest opportunity (average 4.2 weeks) and returned most rapidly (average 6.8 months) to their normal functional activities

(Table 2). Delayed union was observed in three Gustilo grade 3B femoral fractures; however, there were no non-unions. Intramedullary interlocking nails for the tibia were performed for 11 closed, eight Gustilo grade 3A, three Gustilo grade 3B and one Gustilo grade 3C fracture, which united at an average 23.8 weeks. Three non-unions occurred in two grade 3B and one grade 3C open fractures and required distraction histogenesis using a ring fixator. They united between 80 and 90 weeks following injury.

Table 3 Final functional outcome and mode of treatment. Karlstrom and Olerud (1977) [12] criteria used in all studies listed

Study	Treatment	Results				Total
		Excellent	Good	Acceptable	Poor	
Karlstrom and Olerud (1977) [12]	Operative	12	Excellent to good	2	–	14
	Combined	–	–	1	2	3
	Non-operative	–	4	4	2	10
Fraser et al. (1978) [6]	Operative	–	3	6	1	10
	Combined	3	7	15	3	28
	Non-operative	–	5	9	8	22
Bansal et al. (1984) [3]	Combined	1	6	4	1	12
	Non-operative	2	8	14	4	28
Veith et al. (1984) [16]	Operative	13	9	2	–	24
	Combined	7	10	6	–	23
Behr et al. (1987) [4]	Operative	2	2	1	1	6
Hee et al. (2001) [10]	Operative	6	53	25	4	88
Yokoyama et al. (2002) [17]	Operative	25	15	16	12	68
Present study	Intramedullary nail	15	5	–	3	23
	External fixation	3	2	3	6	14
	Combined	4	4	1	2	11
	Non-operative	3	5	3	1	12

Three other tibial fractures in this group required additional procedures. One required exchange nailing and bone grafting and united at 40 weeks while in two, bone grafting alone sufficed. The fractures united at 42 weeks following injury. Excellent to good results were observed in 20 patients while three patients with non-union of the tibia had poor results (Table 3).

External fixation: External fixation was used for eight Gustilo grade 3A and six Gustilo grade 3B open femoral fractures and six Gustilo grade 3A and eight Gustilo grade 3B open tibial fractures. Patients treated with external fixation of the femur spent the least time (average 26.6 days) in hospital (Table 2); however, they had the disadvantage of having undergone a maximum number of surgical procedures (average 3.2) and also had the least range of motion (average 90°) at the knee. Delayed union (26 to 36 weeks) was observed in five femoral fractures. One patient treated with external fixation of the femur had an extension lag of 50°. Five delayed unions of the tibia united at 25, 26, 29, 31 and 36 weeks, respectively, and three amongst them required bone grafting. Three bus drivers treated with external fixation of the femur changed their profession, as stiffness at the knee limited their return to driving. Three patients had excellent results, two good, three acceptable and six poor (Table 3).

Statistical comparison of hospital stay, time to union for femur and tibia, return to work and excellent/good results for all modalities was done. Statistically significant differences between non-operative and combined groups ($p=0.04$) and between non-operative and operative groups ($p=0.03$) for time to return to work were observed.

Final functional results as per Bansal's radiological classification [3] were: group 1—22 excellent results, nine good, four acceptable and ten poor; group 2A—two excellent, four good, one acceptable and one poor; group 2B—one each excellent, good, acceptable and poor; group 3—two good and one acceptable.

Discussion

An expanding population, increasing number of motor vehicles on limited infrastructure of most cities in developing countries, various modes of treatment and their effectiveness made this injury a target of concern from both medical and socio-economic standpoints. Men (54/60) and those 21–30 (26/60) years of age were most commonly involved in road-traffic accidents (57/60), as they are less risk-averse in their driving habits. Male preponderance, a younger age group and high-energy road traffic accidents leading to this injury have been observed [2–6, 10]. The right left was commonly involved (35/60) in line with an earlier report [3]. Others report equal limb involvement [16]. Most femoral fractures were closed (42/60) while most tibial fractures were open (38/60), in line with earlier observations [4, 6, 11, 14]. The middle third of the shaft of

both femur and tibia was most commonly (75%) involved, as in other reports [3, 6]. Concomitant injuries were common [6, 13, 14] and were observed in 40/60 of our patients, and delayed mobilisation in all groups. A higher percentage (27%) of patients underwent amputations compared with the maximum of 25% in other studies [1, 14, 16]. This was probably related to the severity of trauma, massive soft tissue crushing and delay in presentation at the hospital.

Despite a selection bias, where closed and less-displaced fractures were treated by functional bracing, the results were not superior to combined or operative modalities. Non-operative methods also required close monitoring for shortening and angulation. The longest period in hospital, time to fracture union, time to walk and time to return to normal activities (Table 2) made this an unfavourable method of treatment.

As intramedullary nailing of the femur is the key to management [2, 7, 16], and the most favourable results were observed among the patients of this group. Fractured tibiae treated either with functional cast bracing or intramedullary nailing did not interfere with mobilisation, and their average union rates did not differ greatly (Table 2). Union of the femur (20.6 weeks) and tibia (24.4 weeks) are comparable to previous studies [5, 12], as is the earlier return to work (average 8.1 months) [6, 12]. A majority (8/11) of patients had excellent and good results (Table 3), similar to earlier reports [3, 6, 16].

Intramedullary nailing formed the best modality of treatment, with a maximum number of patients with excellent and good results despite injuries of greater severity. However, the affordability and surgical expertise of intramedullary interlock nailing may not be available in all parts of the developing world. Hence, Kuntscher nailing with a thigh lacer to prevent rotation of the comminuted fractured femur may be a viable option and was practiced with favourable results in eight of our patients. The use of intramedullary nails for both fractures is presently the best modality, if resources and surgical expertise is at hand [4, 10, 12, 16, 17].

External fixation was employed in the treatment of comminuted open femoral fractures not amenable to internal fixation primarily. However, due to patients' financial constraints, it could not be replaced by internal fixation when soft tissue coverage was achieved. The results were therefore not encouraging (Table 3), as nearly half the number of patients had a limited range of movement of less than 120°, probably due to the teno-myodesis effect on the extensor mechanism from the external fixator pins [15]. In our experience, this modality should only be used until soft tissue cover is achieved when it should be replaced with internal fixation.

Group 1 patients fared better, with 31/45 excellent to good results in our study as against 8/18 in the study of Bansal et al. [3] and reflects a larger number of femoral fractures stabilised with intramedullary nailing. External fixation when employed in severely comminuted open femoral fractures lead to knee stiffness and 6/10 poor

results, a modality of treatment Bansal et al. [3] did not employ. Tibial fracture, whether treated operatively or non-operatively, did not interfere in knee mobilisation, and time to fracture union was comparable among those treated with combined modality and intramedullary nail.

Better results for juxta-articular fractures in group 2 were observed, with three excellent results and five good results in comparison with Bansal's [3] series where no excellent results were observed; however, their good results are comparable. Better results in this category were probably due to the use of the intramedullary nail and early mobilisation that prevented supra-patellar adhesion [3].

No excellent result was observed in group 3 patients, which is comparable to Bansal's [3] series, and is possibly due to the fact that both fracture and soft tissue injury affect the metaphysis close to the knee and result in stiffness. It may, however, be worthwhile to stabilise these fractures with internal fixation and attempt early joint mobilisation for better results.

Early fracture union, prompt return to activities, better range of movement at the knee and ankle and a higher number of excellent and good long-term functional results among our patients treated with combined and operative (intramedullary nail) modalities made them the favoured methods of treatment. However, intramedullary nailing for both femur and tibia can be expensive in a resource-poor environment, and therefore, combining intramedullary nailing of the femur and functional cast bracing of the tibia may form a cheaper, viable and practicable alternative with comparable results in Bansal group 1[3] injuries. In juxta-articular Bansal group 2 and 3 injuries, internal fixation is preferable in order to preserve knee motion.

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