ORIGINAL PAPER

J.A.K. Toivanen · A. Kyrö · T. Heiskanen
A.-M. Koivisto · P. Mattila · M.J. Järvinen

Which displaced spiral tibial shaft fractures can be managed conservatively?

Accepted: 17 March 2000

Abstract The aim of the present study was to establish a threshold for the initial displacement of a spiral tibial shaft fracture beyond which its retention in an acceptable position cannot be guaranteed by plaster immobilization. We reviewed the records and radiographs of 131 plaster cast-treated patients with spiral tibial shaft fracture, initially displaced 50% or less, for patients whose fracture had either lost its acceptable retention or consolidated in an unacceptable position. The fractures were classified, according to the true initial displacement as measured on the first radiographs, into four pairs of categories using cut-off points of 10, 20, 30 and 40% of the diameter of the tibial diaphysis. Comparison was then made of the proportions of failed treatments between each of these pairs. Plaster cast treatments failed in 28% when the true initial displacement was 30% or less, and in 46% when the true initial displacement was more than 30%. The risk of failed plaster cast treatment increased when true initial displacement exceeded 30%. In all patients whose

plaster cast treatment was interrupted the true initial displacement was more than 30%. We therefore conclude that diaphyseal fractures of the tibia for which the initial displacement exceeds 30% are not suitable for plaster cast treatment.

Résumé L'objectif de cette étude était de déterminer le seuil de déplacement initial des fractures spiroïde du tibia après lequel la position acceptable ne peut être garantie sous immobilisation plâtrée. Nous avons revu les dossiers et les radiographies de 131 patients plâtrés présentant une fracture spiroïde du tibia avec un déplacement initial de 50% ou moins, pour découvrir les patients dont les fractures, soit ont perdu une réduction acceptable, soit se sont consolidées dans une position non-acceptable. Les fractures ont été classées selon le déplacement initial réel, mesurées sur les radiographies d'entrée. Quatre paires de catégories ont été créées en utilisant comme points de mesure, à savoir: 10, 20, 30 et 40% du diamètre de la diaphyse du tibia. Puis les proportions des traitements non réussies entre chacune des ces paires étaient comparées. Les traitements sous plâtre ont abouti à l'échec dans 28% des cas quand le déplacement initial réel était de 30% ou moins, et dans 46% des cas quand le déplacement initial réel était plus que 30%. Le risque de l'échec de traitement par plâtre n'a augmenté que légèrement quand le déplacement initial a dépassé les 30%. Le degré de déplacement initial réel des fractures dont les traitements plâtrés ont été interrompus était de plus de 30%. Ainsi nous aboutissons à la conclusion que les fractures de la diaphyse tibiale dont le déplacement initial dépasse 30% ne conviennent pas pour le traitement par immobilisation plâtrée.

J.A.K. Toivanen · A. Kyrö · T. Heiskanen · A.-M. Koivisto
P. Mattila · M.J. Järvinen
Tampere University Hospital,
University of Tampere and Central Hospital of Central Finland,
Finland

J.A.K. Toivanen · M.J. Järvinen
Division of Orthopaedics and Traumatology,
Department of Surgery, Tampere University Hospital,
P.O. Box 2000, 33521 Tampere, Finland

J.A.K. Toivanen (✉) · M.J. Järvinen
Medical School, University of Tampere,
P.O. Box 607, 33101 Tampere, Finland
e-mail: lljato@uta.fi
Tel: +358-3-2475076, Fax: +358-3-2474358

A. Kyrö · T. Heiskanen
Department of Surgery, Central Hospital of Central Finland,
Finland, P.O. Keskussairaalan tie 19, 40620 Jyväskylä, Finland

A.-M. Koivisto
Tampere School of Public Health, University of Tampere,
P.O. Box 607, 33101 Tampere, Finland

P. Mattila
Department of Radiology, Tampere University Hospital,
P.O. Box 2000, 33521 Tampere, Finland

Introduction

In choosing between conservative and operative treatment of a tibial shaft fracture the stability of the fracture is considered to be an important predictive factor. A spiral fracture with an initial displacement of less than 50%

of the diameter of the shaft is usually considered “good in nature” and thus amenable to conservative treatment [12].

In experimental studies the interosseal membrane and the periosteum of the tibia and fibula have been found to be markedly effective stabilizers [5]. In a fractured leg the integrity of these stabilizing structures will be compromised [15]. Furthermore, the extent of soft tissue damage in general depends on the initial displacement. Böstman [3] has shown that tibial shaft fractures of the spiral type with an initial displacement exceeding 50% of diaphyseal diameter should be treated surgically. However, it remains uncertain whether all spiral fractures with an initial displacement of less than 50% are amenable to plaster cast treatment.

This study was undertaken to determine the critical extent of initial displacement beyond which the risk of loss of reduction or malalignment will increase during cast treatment of spiral tibial shaft fractures initially displaced by less than 50% of the diaphyseal diameter.

Patients and methods

We reviewed retrospectively the records and X-rays of 520 patients treated for tibial diaphyseal fractures at two different hospitals between 1990 and 1995. Of these, cast treatment had been applied as the initial treatment in 360 patients. Twenty-eight patients were excluded from this study because of insufficient X-rays and 19 because of insufficient records.

A patient was eligible for inclusion if the following criteria were met: (1) the patient had an isolated, unilateral, closed or open Gustilo-Andersen grade I fracture of the shaft of the tibia and fibula; (2) fracture was caused by a low energy trauma and its configuration was spiral; (3) initial displacement was less than 50% of the diaphyseal diameter; (4) conservative treatment had initially been applied; (5) the fracture was located in the middle or distal third of the tibial shaft; (6) the patient was at least 15 years old; and (7) there had been no previous fracture in the injured leg. These criteria were fulfilled for 131 patients (Table 1).

True initial displacement was assessed from the first radiographs (Fig. 1) [3]. Shortening was measured either by comparing the radiographs of the injured leg with those of the opposite leg (88 cases) or solely on the basis of radiographs obtained of the injured leg. Rotational malalignment was assessed clinically.

The patients were followed in the outpatient clinics of the two hospitals. The examinations included roentgenograms, which were

Fig. 1 True initial displacement was calculated as follows: $D_T = \sqrt{D_C^2 + D_S^2}$, coronal (D_C) and sagittal (D_S) displacement measured on anteroposterior and lateral X-rays, respectively

repeated until union was established and the patient had resumed normal activities. Treatment was considered successful if the following criteria were fulfilled: (1) the fracture was maintained in plaster and managed non-surgically; (2) angulation in the coronal plane was less than 5°, in the sagittal plane less than 10° and shortening less than 10 mm; and (3) there was no clinically rotational malalignment.

Surgical intervention was eventually undertaken if displacement exceeded half the diaphyseal width or shortening exceeded 10 mm. No repeated reductions were performed. Correction of excessive angulation was attempted by wedging the cast. During the first 6 weeks the patients were instructed to bear limited weight. Full weight-bearing would normally be achieved at 12 weeks. If the fracture was sufficiently stable at 6 weeks the treatment was continued with a below-knee cast or a patellar-tendon-bearing cast.

To describe the data, medians (range) are reported for continuous variables. For categorised variables, percentages are used. Comparison of continuous variables was done by Mann-Whitney test. In the case of nominal variables the chi-square test was used. To determine the critical extent of displacement above which the

Table 1 Effects of sex, fracture site, open/closed fracture ratio, age and magnitude of true initial displacement on the outcome of treatment

Variable	Successful t conservative treatment	Failed conservative treatment	P-value
Sex			
Male (n=81)	65%	35%	0.393 ^a
Female (n=50)	58%	42%	
Site of fracture			
Distal (n=22)	61%	39%	0.282 ^a
Middle (n=109)	73%	27%	
Open/closed fracture ratio			
Closed (n=124)	64%	36%	0.267 ^a
Open (n=7)	43%	57%	
Median age, years (range)	42 (16–87)	44 (24–74)	0.053 ^b
Median magnitude of true initial displacement (range) (n=131) ^c	30% (0.15%–0.50%)	38% (0.14%–0.50%)	0.034 ^b

^a Pearson chi-square

^b Mann-Whitney test

^c percentage of the diameter of the tibial diaphysis

risk of lost retention or development of malunion increased, the true initial displacements were classified into pairs of categories using cut-off points of 10, 20, 30 and 40% of the diaphyseal diameter.

Comparison was then made of the proportions of failed treatments (inability to retain the fragments in an acceptable position or consolidation of the fragments in an unacceptable position) between each of these pairs. The risk of unsuccessful treatments and its confidence interval was also calculated. Logistic regression analysis was used to establish whether initial displacement was an independent risk factor for successful/unsuccessful treatment. Initial displacement, gender, age, fracture pattern and fracture site was included in the logistic regression analysis.

Intra- and interobserver reliability was analyzed. The maximal error, the measurement error and the 95% confidence interval of the error were calculated. The statistical analyses were carried out using the SPSS for Windows program (Version 8.0; SPSS Inc.). Throughout the study, a *P*-value of less than 0.05 was considered significant.

Results

The characteristics of the patients can be seen in Table 1. In 24 fractures closed treatment was changed due to malalignment. The common denominator for all these fractures was an initial displacement between 30% and 50% of the diaphyseal diameter. The median time from injury to operation was 7 days (range, 2–49 days). In 23 fractures intramedullary nailing was performed, in one plating.

The different malunited fractures according to malalignment can be seen in Table 2. Seven fractures had more than one malalignment at the fracture site. The risk of malunion or loss of reduction was significantly higher when the initial displacement exceeded 30% or 40% of the diaphyseal diameter (Table 3). Closed cast treatments failed in 28% when the true initial displacement was 30% or less, and in 46% when the true initial displacement was more than 30% (Table 3).

Table 2 Distribution of malunited fractures according to malalignment

Type of malunion	Number of fractures	Percentage
Varus >5°	2	6
Valgus >5°	4	12
Antecurvatum >10°	0	0
Recurvatum >10°	1	3
Shortening >10 mm	16	48
Rotational malunion >10° ^a	10	31
Total	33	100

^a In this material there were only externally malrotated fractures.

Table 3 Risk of lost retention or development of malalignment at various cut-off points of true initial displacement among fractures in 131 patients (*CI* confidence interval)

True initial displacement (%)	Number of failed treatments (%)	Number of successful treatments (%)	<i>P</i> -value	Odds ratio (95% CI)
≤20	5 (28)	13 (72)	0.363 ^a	1.66 (0.55–4.97)
>20	44 (39)	69 (61)		
≤30	17 (28)	44 (72)	0.035 ^a	2.18 (1.05–4.53)
>30	32 (46)	38 (54)		
≤40	29 (31)	64 (69)	0.021 ^a	2.45 (1.13–5.31)
41–50	20 (53)	18 (47)		

^a Pearson chi-square

Table 4 Results of the logistic regression analysis at each cut-off point of true initial displacement

Variable	Odds ratio	95 Confidence interval	<i>P</i> -value
Cut-off point 20%			
True initial displacement			
≤20%	Reference		
>20%	1.845	0.595–5.725	0.289
Fracture site			
Middle	Reference		
Distal	2.153	0.735–6.301	0.162
Sex			
Male	Reference		
Female	1.132	0.512–2.502	0.759
Age	1.014	0.988–1.042	0.296
Closed/open fracture ratio			
Open	Reference		
Closed	2.467	0.483–12.593	0.278
Cut-off point 30%			
True initial displacement			
≤30%	Reference		
>30%	2.276	1.074–4.823	0.032
Fracture site			
Middle	Reference		
Distal	1.965	0.667–5.789	0.220
Sex			
Male	Reference		
Female	1.121	0.502–2.503	0.780
Age	1.016	0.988–1.044	0.268
Closed/open fracture ratio			
Open	Reference		
Closed	2.697	0.510–14.243	0.243
Cut-off point 40%			
True initial displacement			
≤40%	Reference		
>40%	2.933	1.290–6.667	0.010
Fracture site			
Middle	Reference		
Distal	2.495	0.819–7.601	0.108
Sex			
Male	Reference		
Female	1.054	0.417–2.156	0.900
Age	1.021	0.993–1.050	0.143
Closed/open fracture ratio			
Open	Reference		
Closed	2.651	0.502–14.007	0.251

Table 5 Assessment of intra- and interobserver variation in measurements of true initial displacement (CI confidence interval)

	<i>n</i>	Maximal error (%)	Measurement error ^a (%)	95% CI
Intraobserver				
Observer 1	10	12	3	0–11%
Observer 2	10	15	6	0–14%
Interobserver	10	20	6	0–18%

^a Standard deviation of corresponding measurements

The only variable which differed significantly between successfully and unsuccessfully treated patients was the magnitude of the initial displacement (Table 1). Neither gender, open/closed fracture ratio, patient's age, nor the site of the fracture had any significant predictive value in determining success of treatment (Table 4). On the other hand, the initial displacement was a statistically significant predictor for successful treatment at cut-off points at least 30% of the diameter of the tibial shaft. The intra- and interobserver variation in measurements seemed to be acceptable (Table 5).

Discussion

The risk of failed plaster cast treatment increased significantly when the true initial displacement exceeded 30% as against 30% or less. However, the risk increased less than twice with confidence intervals whose lower limit was close to one and with a maximal measurement error varying between 12 and 20%. This increased risk alone has minor clinical significance. On the other hand, an unacceptable proportion (46%) of treatments failed when the true initial displacement exceeded 30% of the tibial diaphyseal diameter. In addition, it has to be noted that the true initial displacement of all fractures where initial reduction could not be maintained was between 30% and 50%.

Our results should however be carefully considered against the risks of intramedullary nailing. Deep infection is the most serious complication with an incidence of 1–3% in fractures of minor or moderate severity [10]. Secondly, inaccurate nailing may result in malalignment. However, satisfactory alignment control has been repeatedly reported [2,6,7]. Thirdly, the incidence of non-union after reamed intramedullary nailing is 0–2% [1,2], whereas it is 6% after conservative treatment [1]. The risks attributable to static intramedullary nailing may be considered reasonable and do not hinder its use in the treatment of low-energy fractures of the tibial diaphysis.

The results of the present study suggest that the former 50% threshold of initial displacement should be lowered [3]. In daily routine lowering the threshold to 30% means that most low-energy tibial fractures will have to be treated surgically. The description of malalignment as being compatible with good long-term function remains contro-

versial [4,8,11,13,14,17,18]. We have used the most common guidelines for an acceptable reduction of a tibial shaft fracture [4,9,16]. We conclude that in spiral, closed or grade I open, tibial shaft fractures in the middle or lower third of the shaft, with concomitant fibular fracture and with a true initial displacement exceeding 30% of the diaphyseal diameter, the incidence of loss of reduction after cast treatment is unacceptably high.

In this study the incidence of malalignment and that of failed reduction was comparable to earlier reports for conservative management [4,16].

References

1. Alho A, Ekeland A, Strømsøe K, Follerås G, Thorsen BO (1990) Locked intramedullary nailing for displaced tibial shaft fractures. *J Bone Joint Surg [Br]* 72:805–809
2. Alho A, Benterud JG, Høgevoid HE, Ekeland A, Strømsøe K (1992) Comparison of functional bracing and locked intramedullary nailing in the treatment of displaced tibial shaft fractures. *Clin Orthop* 277:243–250
3. Bostman OM (1986) Spiral fractures of the shaft of the tibia. Initial displacement and stability of reduction. *J Bone Joint Surg [Br]* 68:462–466
4. Bostman O, Hanninen A (1982) The fibular reciprocal fracture in tibial shaft fractures caused by indirect violence. *Arch Orthop Trauma Surg* 100:115–121
5. Charnley J (1963) The closed treatment of common fractures. 3rd edn. Churchill Livingstone, Edinburgh London New York, pp 205–249
6. Collins DN, Pearce CE, McAndrew MP (1990) Successful use of reaming and intramedullary nailing of the tibia. *J Orthop Trauma* 4:315–322
7. Gad HF, Abul KI, Booz MK (1990) Closed nailing of tibial shaft fractures. *Injury* 21:217–219
8. Goodman SB, Lee J, Smith RL, Csongradi JC, Fornasier VL (1991) Mechanical overload of a single compartment induces early degenerative changes in the rabbit knee. A preliminary study. *J Invest Surg* 4:161–170
9. Johner R, Wruhs O (1983) Classification of tibial shaft fractures and correlation with results after rigid internal fixation. *Clin Orthop* 178:7–25
10. Maatz R (1983) Zur Infektionshäufigkeit nach gedeckter oder offener Nagelung geschlossener Frakturen. *Aktuel Traumatol* 13:175–178
11. McKellop HA, Llinas A, Sarmiento A (1994) Effects of tibial malalignment on the knee and ankle. *Orthop Clin North Am* 25:415–423
12. Nicoll EA (1964) Fractures of the tibial shaft. A survey of 705 cases. *J Bone Joint Surg [Br]* 46:373–387
13. Oni OO, Hui A, Gregg PJ (1988) The healing of closed tibial shaft fractures. The natural history of union with closed treatment. *J Bone Joint Surg [Br]* 70:787–790
14. Puno RM, Vaughan JJ, Stetten ML, Johnson JR (1991) Long-term effects of tibial angular malunion on the knee and ankle joints. *J Orthop Trauma* 5:247–254
15. Sarmiento A, Latta L, Zilioli A, Sinclair W (1974) The role of the soft tissues in the stabilization of tibial fractures. *Clin Orthop* 105:116–129
16. Slatits P, Rokkanen P (1967) Conservative treatment of tibial shaft fractures. Principles and results of treatment. *Acta Chir Scand* 134:41–47
17. Trafton PG (1988) Closed unstable fractures of the tibia. *Clin Orthop* 230:58–67
18. Waddell JP, Reardon GP (1983) Complications of tibial shaft fractures. *Clin Orthop* 178:173–178