Review Article
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CLOSED TIBIAL SHAFT FRACTURES: MANAGEMENT AND TREATMENT COMPLICATIONS. A REVIEW OF THE PROSPECTIVE LITERATURE

Chad P. Coles, MD; Michael Gross, MD

OBJECTIVE: To compare the results and complications of the various modalities for treating closed fractures of the tibial shaft described in the prospective literature.

DATA SOURCES: A MEDLINE search of the English language literature from 1966 to 1999 was conducted using the MeSH heading "tibial fractures." Studies pertaining to the management of closed tibial shaft fractures were reviewed, and their reference lists were searched for additional articles.

STUDY SELECTION: An analysis of the relevant prospective, randomized controlled trials was performed. Studies including confounding data on open fractures or fractures in children were excluded. The 13 remaining studies were reviewed.

DATA EXTRACTION: Raw data were extracted and pooled for each method of treatment.

DATA SYNTHESIS: The 13 studies described 895 tibial shaft fractures treated by application of a plaster cast, fixation with plate and screws, and reamed or unreamed intramedullary nailing. Although definitions varied, the combined incidence of delayed and nonunion was lower with operative treatment (2.6% with plate fixation, 8.0% with reamed nailing and 16.7% with unreamed nailing) than with closed treatment (17.2%). The incidence of malunion was similarly lower with operative treatment (0% with plate fixation, 3.2% with reamed nailing and 11.8% with unreamed nailing) than with closed treatment (31.7%). Superficial infection was most common with plate fixation (9.0%) compared with 2.9% for reamed nailing, 0.5% for unreamed nailing and 0% for closed treatment. The incidence of osteomyelitis was similar for all groups. Rates of reoperation ranged from 4.7% to 23.1%.

CONCLUSIONS: All forms of treatment for tibial shaft fractures are associated with complications. A knowledge of the incidence of each complication facilitates the consent process. To fully resolve the controversy as to the best method of treatment, a large, randomized, controlled trial is required. This review more precisely predicts the expected incidence of complications, allowing the numbers of required patients to be more accurately determined for future randomized controlled studies.

OBJECTIF : Comparer les résultats et les complications des diverses méthodes de traitement de fractures fermées du corps du tibia décrites dans les documents prospectifs.

SOURCES DE DONNÉES : On a cherché dans MEDLINE des documents publiés en anglais de 1966 à 1999 en utilisant la vedette-matière MeSH « tibial fractures ». On a passé en revue des études portant sur la prise en charge des fractures fermées du corps du tibia et effectué des recherches dans leurs listes de références pour trouver d'autres articles.

SÉLECTION DES ÉTUDES : On a procédé à une analyse des études contrôlées randomisées prospectives pertinentes. On a exclu les études qui comportaient des données prêtant à confusion sur les fractures ouvertes ou les fractures chez les enfants. Les 13 autres études ont été passées en revue.

EXTRACTION DES DONNÉES : On a extrait des données brutes qu'on a regroupées pour chaque méthode de traitement.

SYNTHÈSE DES DONNÉES : Les 13 études décrivaient 895 fractures du corps du tibia traitées par pose d'un plâtre, par fixation au moyen d'une plaque et de vis et par clouage intramédullaire avec ou sans alésage. Même si les

From the Division of Orthopaedic Surgery, Dalhousie University, Halifax, NS

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Correspondence to: *Dr. Chad P. Coles, Division of Orthopaedic Surgery, Queen Elizabeth II Health Sciences Centre, Level 400, Halifax Infirmary Site, 1796 Summer St., Halifax, NS B3H 3A7; colesc@is2.dal.ca*

définitions variaient, l'incidence combinée des retards de consolidation et de non consolidation était moins élevée dans le cas de l'intervention (2,6 % avec fixation par plaque, 8,0 % par clouage avec alésage et 16,7 % par clouage sans alésage) que dans celui du traitement fermé (17,2 %). L'incidence de cal vicieux était de même moins élevée dans le cas de l'intervention (0 % pour la fixation par plaque, 3,2 % pour le clouage avec alésage et 11,8 % pour le clouage sans alésage) que dans le cas du traitement fermé (31,7 %). L'infection superficielle a été la plus fréquente dans les cas de fixation par plaque (9,0 %) que dans les cas de clouage avec alésage (2,9 %), de clouage sans alésage (0,5 %) et de traitement fermé (0 %). L'incidence d'ostéomyélite a été la même pour tous les groupes. Les taux de nouvelle intervention ont varié de 4,7 % à 23,1 %.

CONCLUSIONS : Toutes les méthodes de traitement des fractures du corps du tibia entraînent des complications. Une connaissance de l'incidence de chaque complication facilite l'obtention du consentement. Afin d'éliminer complètement la controverse qui règne au sujet de la meilleure méthode de traitement, il faut procéder à une étude contrôlée randomisée d'envergure. Cette étude permet de prévoir avec plus de précision l'incidence attendue de complications et de déterminer avec plus de précision le nombre de patients nécessaires pour procéder à de futures études contrôlées randomisées.

Closed fractures of the tibial shaft are common. Despite a large number of studies published on this topic, controversy still exists as to the best method of treatment. The purpose of this paper is to review the results of prospective studies published on this topic in the past 30 years to identify the relative incidence of the reported complication associated with different methods of treatment.

Methods

A MEDLINE search of the English language literature from 1966 to 1999 inclusive was conducted using the MeSH heading "tibial fractures." All papers pertaining to the management of closed tibial shaft fractures were reviewed. The reference lists of these papers were also searched for additional articles. From these papers, only studies with a prospective design were selected. Data on time to fracture healing, numbers of delayed union, nonunion and malunion, incidence of infection, and other complications were extracted from each study and combined for each method of treatment.

Results

Eight randomized controlled trials and an additional 19 prospective studies were identified. The lack of sufficient randomized controlled trials precluded a meta-analysis from being performed, according to published criteria.[1] Three randomized controlled trials and 11 prospective studies were discarded because the relevant data were not extractable from confounding data on open fractures or fractures in children. The results of the remaining 13 studies are presented below and summarized for each method of treatment.

Blachut and associates[2] randomized 136 closed tibial shaft fractures to treatment by reamed or unreamed intramedullary nailing. The mean age of the patients was 35 years, with motor vehicle accidents being the cause of injury in 40% of cases. In the 73 patients treated with reamed nailing, 7 patients had delayed union requiring dynamization and 3 patients had nonunion (2 treated with exchange nailing and 1 treated with bone grafting). The mean time to union was not reported. There were 3 cases of malunion (more than 5° angulation, more than 15° rotation or more than 1 cm of shortening). One case each of deep venous thrombosis, fat embolism, pulmonary embolism and arrhythmia were reported. There were also 3 cases of compartment syndrome, 1 broken nail (in one of the cases of nonunion), 2 broken screws, and 4 cases in which the screws backed out. Ten prominent locking screws were electively removed. In the 63 patients treated with unreamed nailing, 10 had delayed union requiring dynamization and 7 had nonunion, of whom 5 were treated with exchange reamed nailing and 1 was treated with plate fixation. Two patients had malunion, and 1 had compartment syndrome, leading to deep infection. Two patients had deep venous thrombosis, and 2 had pneumonia. Screws broke in 10 cases, and backed out in 2 cases. Ten prominent locking screws were electively removed.

Court-Brown and associates[3] randomized 50 Tscherne C1 closed tibial shaft fractures to treatment by reamed or unreamed intramedullary nailing. The mean age of the patients was 35.5 years, with the mechanism of injury being motor vehicle accident in 25% and low-energy injuries in the remainder. Early weight bearing was encouraged postoperatively. In the 25 patients treated with reamed nails, the mean time to union was 15.4 weeks, with no delayed union or nonunion, malunion or infections. There were 2 cases of compartment syndrome and 1 broken screw. In the 25 patients who had unreamed nailing, union was achieved in a mean of 22.8 weeks. There were 5 cases of atrophic nonunion at 12 weeks (treated by exchange nailing) and 4 cases of malunion (more than 5° malalignment or more than 1 cm shortening), with no infections and 3 cases of compartment syndrome. One patient had a broken nail and required reoperation, and there were 13 broken screws.

Chiu and associates[4] randomized 76 Winquist–Hansen types I to IV closed fractures to treatment by nailing with either reamed or Ender nails. The mean age of the patients was 44.5 years, with the majority of fractures resulting from motor vehicle accidents. The fractures treated with Ender nails are excluded from our analysis. In the 44 fractures treated with reamed nailing, the mean time to union was 15.1 weeks, with no delayed union. There were 4 superficial infections, 1 screw backed out requiring removal, and in 1 patient loss of reduction was treated by exchange nailing 2 weeks postoperatively.

In a second paper, Chiu and colleagues[5] randomized 116 additional Winquist–Hansen types I to IV closed fractures to similar treatment by reamed nailing or Ender nailing. The mean patient age was 42 years. Again the results of Ender nailing were excluded. The 60 tibial fractures treated by reamed nailing united in a mean of 14.2 weeks with no cases of delayed union, nonunion or malunion, and 3 superficial wound infections. Three screws backed out and were removed. One patient required exchange nailing at 4 weeks for loss of reduction.

Abdel-Salam and associates[6] randomized 90 closed fractures to either closed reduction and long-leg plaster casting, or open reduction and internal fixation with a direct compression plate. The mean age of the patients was 27.4 years, and all fractures were the result of sporting injuries. The mean time to union was not reported. Of the 45 patients treated by plaster casting, there were 6 cases of nonunion requiring bone grafting and 7 cases of malunion (more than 10° angulation or 2.5 cm shortening). One patient had osteomyelitis after bone grafting for nonunion. Seven patients required cast wedging, 5 required remanipulation, and 2 required operation for loss of reduction. There was 1 case of compartment syndrome. Of the 45 patients treated by plate fixation, 1 had delayed union (united at 25 weeks), and 2 had superficial infection.

Uhlin and Hammer[7] prospectively studied 38 closed fractures preferentially treated with unreamed nailing, or where necessary by reamed nailing. The mean patient age was 43 years, and the majority of injuries were of low energy. In the 27 patients treated with unreamed nailing, the mean time to union was 16.0 weeks, with 5 cases of delayed union (more than 24 weeks) managed by dynamization. There were no cases of malunion or infection. Compartment syndrome occurred in 2 patients, 1 patient suffered deep venous thrombosis, and there were 4 broken screws. In the 11 patients treated with reamed nailing, the mean time to union was 13.4 weeks, with 1 case of delayed union requiring dynamization. One patient had nonunion treated successfully with exchange reamed nailing and bone grafting. There were 2 cases of compartment syndrome.

Harrington and associates[8] prospectively studied 29 Winquist–Hansen types I to IV closed fractures treated with unreamed tibial nailing. The mean age of these patients was 36.3 years. Six fractures were the result of motor vehicle accidents, with the remaining fractures resulting from low-energy injuries. The mean time to union was 14.9 weeks. One patient had both delayed union and malunion (more than 5° angulation). There were no infections. One patient died of fat embolism, and 1 had compartment syndrome. One patient had a transient peroneal nerve palsy. There was 1 broken screw and there were 2 bent screws with premature weight bearing, and 1 patient had penetration of the ankle joint with early weight bearing. One patient required reoperation for malalignment.

Twenty-one closed tibial fractures associated with extensive soft-tissue injury, treated with unreamed nailing were prospectively studied by Krettek and associates.[9] The mean age of their patients was 34 years. The majority of fractures occurred as a result of motor vehicle accidents. The mean time to union was 23.3 weeks. There were 14 cases of malunion (more than 5° angulation or rotation, and more than 1 cm shortening). Two patients required reoperation for loss of reduction: 1 was treated with exchange reamed nailing and the other with plate fixation. Both required bone grafting. There was 1 case of osteomyelitis in the patient treated with exchange nailing. One fracture was treated with a subsequent isolated bone graft procedure. Five patients required early dynamization, and there were 3 broken screws. Given the degree of soft-tissue injury, prophylactic fasciotomies were performed in all cases. One patient suffered pulmonary embolism with satisfactory resolution of the condition.

Wiss and colleagues[10] prospectively followed 101 Winquist–Hansen types I to IV closed fractures treated with reamed intramedullary nailing. The mean patient age was 32 years, and the majority of fractures resulted from motor vehicle accidents. These fractures united in a mean of 28 weeks. There were 11 cases of delayed union; dynamization was performed in 3 of them, 1 was treated with exchange reamed nailing and 1 with external fixation and bone grafting. There were 2 cases of nonunion: 1 fracture was treated with exchange reamed nailing and the other with plate fixation. Five cases of malunion (more than 7° angulation or more than 1 cm shortening) were reported. There were 2 superficial infections and 3 cases of osteomyelitis. Five patients had a transient nerve palsy.

Thirty-eight patients who had Winquist–Hansen types III and IV closed tibial fractures treated with unreamed nailing were followed up prospectively by Gregory and associates.[11] The mean age of these patients was 30 years, and the majority of fractures resulted from motor vehicle accidents. The mean time to union was 21.2 weeks. There were 2 cases of delayed union (more than 26 weeks), 1 of which required bone grafting. There were 3 cases of nonunion (longer than 39 weeks), all successfully managed with exchange reamed nailing, and 3 cases of malunion (greater than 5° angulation, more than 10° rotation or more than 1 cm shortening). One patient had a superficial infection, and in the patient with delayed union osteomyelitis developed after bone grafting.

One hundred closed fractures, treated in long-leg plaster cast, were followed prospectively by Oni and colleagues.[12] The mean age of the patients was 34.7 years, and 30% of the fractures resulted from high-energy injuries. The mean time to union was not reported; however, there were 19 cases of delayed union (longer than 20 weeks) and 39 cases of malunion (more than 5° angulation or more than 1 cm shortening). Four cases of delayed union were treated operatively.

Batten and associates[13] prospectively studied 97 Winquist–Hansen type I to IV closed fractures treated according to Association for Osteosynthesis (AO) principles with plate and screws. The mean age of the patients was 34 years. The mean time to union was 14.9 weeks (excluding nonunion), with 4 cases of nonunion (in which reoperation was required). There was no comment on malunion. Superficial infection occurred in 8 patients. There was 1 loose plate and 1 broken plate, which necessitated reoperation. There was 1 case of pulmonary embolism and there were 2 cases of fat embolism.

Finally, Olerud and Karlström[14] prospectively studied 91 closed tibial fractures treated with AO plate and screws. Motor vehicle accident was the cause of injury in 40% of cases. The mean time to union was not calculated; however, there was 1 case of delayed union. There were 11 cases of superficial infection and there was 1 case of osteomyelitis. There were 4 broken or bent plates and there was 1 loose plate requiring reoperation. Three patients suffered refracture after removal of hardware. There was 1 case of fat embolism.

Combined results

The combined results of all studies involving the management of tibial shaft fractures in long-leg plaster cast yielded 145 fractures. The mean time to healing was not reported. There were 19 cases (13.1%) of delayed union, 6 cases (4.1%) of nonunion, and 46 cases (31.7%) of malunion. There was 1 case of osteomyelitis after bone grafting for nonunion and 1 case of compartment syndromes. Seven casts required wedging and 5 patients required repeat manipulation. Twelve patients (8.3%) required subsequent operation: 2 for loss of reduction and 10 for delayed or nonunion.

Of the 233 fractures treated with plate fixation, 97 (41.6%) healed in a mean of 14.9 weeks, with 2 cases (0.86%) of delayed union, 4 cases (1.7%) of nonunion and no cases of malunion. There were 21 cases (9.0%) of superficial infection and there was 1 case (0.4%) of osteomyelitis. Subsequent operations were required in 11 patients (4.7%): 7 for failure of fixation and 4 for nonunion. There were 3 cases of fat embolism and there was 1 case of pulmonary embolism. Three patients suffered refracture after hardware removal.

Unreamed intramedullary nailing in 203 patients resulted in a mean time to union in 140 patients (69.0%) of 19.5 weeks. There were 19 cases (9.4%) of delayed union, 15 cases (7.4%) of nonunion and 24 cases (11.8%) of malunion. Superficial infection occurred in 1 case (0.5%) and osteomyelitis occurred in 3 cases (1.5%). Thirty-one patients (15.3%) required reoperation for delayed or nonunion; 3 patients with delayed union had dynamization and 2 required bone grafting; 13 cases of nonunion were treated by exchange nailing and 1 was treated by plate fixation and bone grafting. Two patients required operation for loss of reduction, and 1 for malunion. There was 1 broken nail, there were 31 broken screws and 2 bent screws, and 2 screws backed out. The ankle joint was penetrated in 1 patient with early weight bearing. Eight patients had a compartment syndrome, 3 had deep venous thrombosis, 1 had fat embolism, 2 had pneumonia and 1 had a transient nerve palsy.

Reamed intramedullary nailing in 314 cases resulted in a mean healing time in 241 patients (76.8%) of 20.2 weeks. Delayed union occurred in 19 cases (6.1%), nonunion in 6 cases (1.9%) and malunion in 10 cases (3.2%). Nine patients (2.9%) had a superficial infection, and osteomyelitis developed in 3 patients (1.0%). Nineteen patients required reoperation for delayed union or nonunion: in 11 patients with delayed union dynamization was carried out; 1 was treated with bone grafting; and 1 with exchange nailing; 5 patients with nonunion were treated with exchange nailing; and 1 was treated with plate fixation and bone grafting. Two patients required reoperation for loss of reduction. There was 1 broken nail and there were 3 broken screws, and 8 screws backed out. There was 1 case each of deep venous thrombosis, pulmonary embolism, fat embolism and arrhythmia. Compartment syndrome developed in 5 patients and 5 had transient nerve palsy.

When the measures of outcome (mean time to union, rates of delayed union or nonunion, malunion, complications and reoperation) were compared for each method of treatment the following data were obtained.

The mean time to union was 14.9 weeks with plate fixation, 19.5 weeks with unreamed nailing and 20.2 weeks with reamed nailing. There was no mention of mean time to healing with closed management of tibial fractures.

Operative treatment had lower rates of delayed or nonunion than closed treatment (Fig. 1) The lowest combined rate of delayed union or nonunion was with plate fixation

(2.6%), followed by reamed nailing (8.0%) and unreamed nailing (16.7%). With closed treatment, the incidence of delayed or nonunion was 17.2%.

The lowest incidence of malunion was found with plate fixation (0%, *n* =136, Fig. 2). This was closely followed by reamed nailing with 3.2%, and unreamed nailing with 11.8% malunion. The incidence of malunion with closed treatment (31.7%) was more than double that of unreamed nailing, and 10 times that of reamed nailing or plate fixation.

There was no report of superficial infection or osteomyelitis with primary closed treatment (1 case of osteomyelitis following a bone graft procedure). The lowest overall surgical superficial infection rate was with unreamed nailing at 0.5%. This was followed by reamed nailing at 2.9% and plate fixation at 9.0% (Fig. 3). The incidence of osteomyelitis was 0.4% with plate fixation, 1.0% with reamed nailing and 1.5% with unreamed nailing.

The rates of reoperation for all forms of treatment varied: 4.7% with plate fixation, 8.3% with closed treatment, 12.4% with reamed nailing, and 23.1% with unreamed nailing (Fig. 4). These rates do not include plate or nail removal after fracture healing, which was seldom described, and they do include locking screw removal for dynamization or screw prominence, which increases the operative rates for intramedullary nailing. If these minor procedures are excluded, the operative rate drops to 5.7% for reamed nailing and 16.7% for unreamed nailing. This makes the rates of reoperation comparable for all groups. It does not take into consideration the frequent practice of removing plate and screws after fracture healing, whereas intramedullary devices tend to be removed only if they cause symptoms.

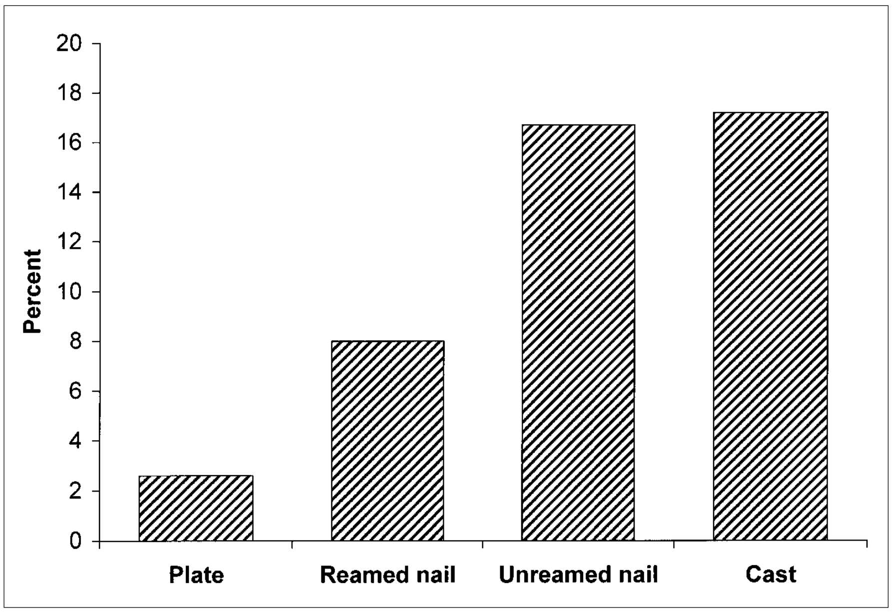

FIG. 1. Combined incidence of delayed and nonunion for each treatment method.

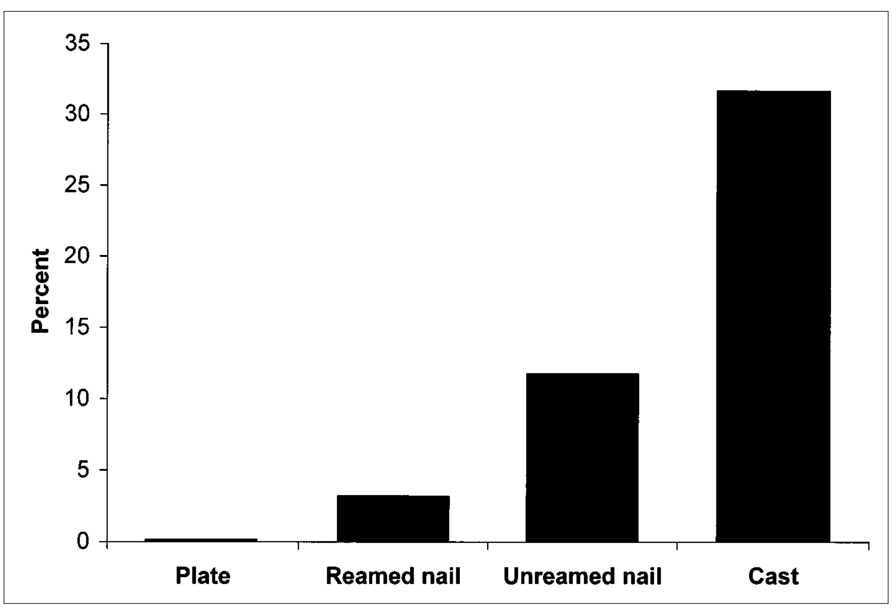

FIG. 2. Combined incidence of malunion for each treatment method.

Discussion

We included only data from prospective studies in this review. The statistical strength of retrospective data is weak, and bias is too large a problem with retrospective data collection and interpretation to merit their inclusion in any meaningful analysis. We were unable to perform a meta-analysis because there was an insufficient number of randomized controlled trials with appropriate data.[1] Unlike the attempt at meta-analysis by Littenberg and associates,[15] we included only prospective data.

The pooled data from the 13 prospective studies described 895 tibial shaft fractures treated with cast immobilization, plate fixation, and unreamed or reamed intramedullary nailing. Small numbers of fractures treated with Ender nails were reported in 2 papers,[4,5] but we did not include them in our analysis.

Some bias may exist in that papers on cast treatment and plate fixation tended to be published in the earlier literature, whereas reports of reamed and unreamed nailing were more often found in the recent literature. Operative techniques have undoubtedly changed over the last 30 years. Another factor to consider is the severity of the fracture pattern, with more low-energy injuries treated by casting, and a tendency for higher grade fractures to be managed by unreamed nailing.

The analysis and comparison of these studies was complicated by a number of factors. Four papers did not comment on one or more of the outcome measures in question.[2,6,13,14]

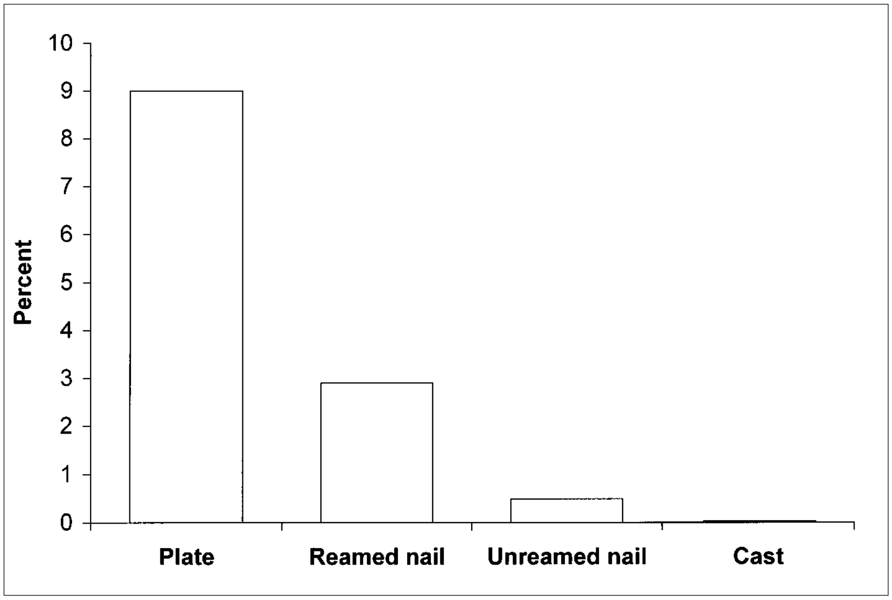

FIG. 3. Combined incidence of superficial infection for each treatment method.

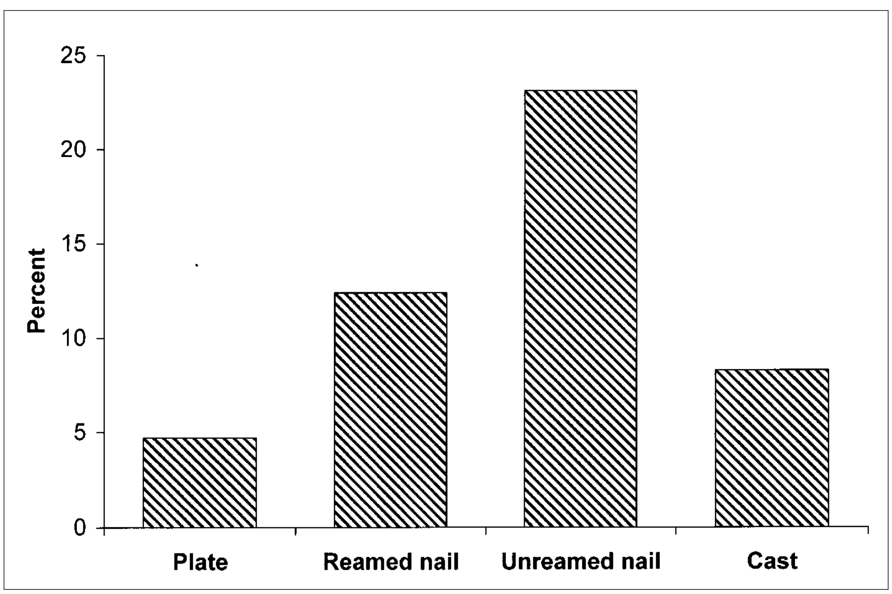

FIG. 4. Combined rates of reoperation for each treatment method.

Pooled data, therefore, were sometimes based on smaller numbers than the total number of fractures, in particular the mean time to union. The criteria for malunion were also varied, ranging from 5° of varus, valgus, and anterior or posterior angulation, 1 cm of shortening, and 5° of rotation in most studies, to as high as 10° of angulation and 2.5 cm of shortening.[7]

The time criteria for delayed union ranged from 12 to 26 weeks,[2,9] with 20 weeks the most commonly cited cutoff time.[7,12] Likewise, the determination of nonunion was made at varying times, ranging from 12 to 39 weeks.[3,11] It was not possible to use a standard definition for delayed or nonunion in the combined analysis of the studies.

Overall, treatment of tibial shaft fractures by casting was associated with the lowest incidence of infection but the highest incidence of delayed union, nonunion and malunion (Fig. 5). Plate fixation had fewer complications of delayed union, nonunion and malunion but more frequent wound complications. Intramedullary fixation had results between these 2 groups, with superior results obtained by reamed nailing, with less delayed union, nonunion, malunion and screw breakage than with unreamed nailing.

In the absence of adequate randomized controlled trials to permit the usual meta-analysis, pooled results from prospective studies provide more useful data than individual studies themselves. Because many different surgeons contribute to the data, the results should be generalizable to the general orthopedic surgeon's practice. This type of data analysis allows individual surgeons and their patients some guidance as to the complication rates of various modalities of treatment of closed tibial fractures.

This study demonstrates that all forms of treatment for closed tibial fractures carry with them a real risk of complications, and that complications are an unavoidable consequence of

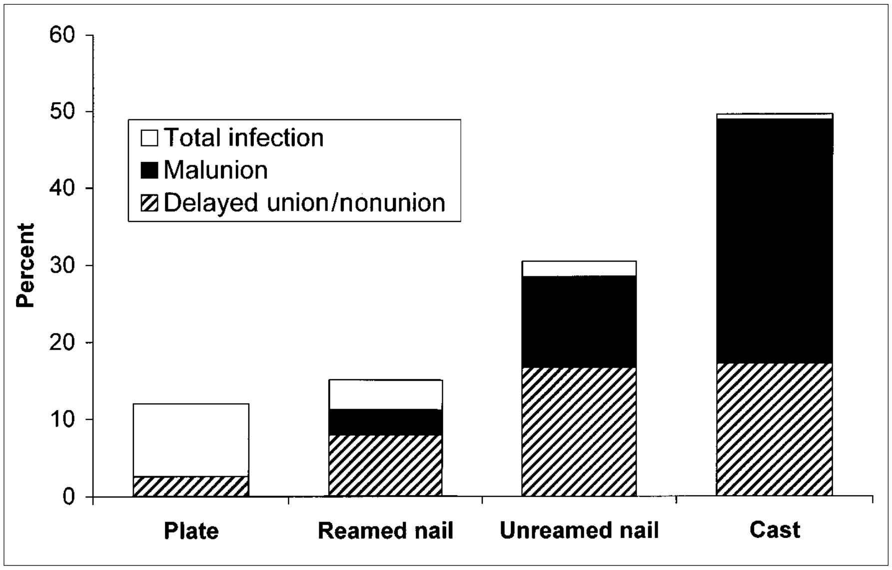

FIG. 5. Combined complications of delayed union, nonunion, malunion and total infection for each treatment method.

tibial fracture management. Different complications have varying consequences on final outcome. Part of the informed consent process must allow for the likelihood and magnitude of these complications to be conveyed to the patient. Pooled data from multiple studies helps this process.

That lack of uniform definitions for delayed union and nonunion, as well as acceptable criteria for malunion complicate the comparison of studies. Some of the studies failed to report all relevant data, making detailed analysis impossible. We believe that stratification of patients according to injury severity would be appropriate in analysing outcomes and complications

CONCLUSIONS

Despite the use of pooled data, there is no clear answer as to which form of treatment is the best for closed fractures of the tibial shaft. The data in this review will allow future researchers to determine what the complication rates are likely to be with the various fracture treatments. The numbers of patients required for future randomized studies could be more accurately determined, based upon the incidence of complications cited in this study. Since the incidence of the different complications is low and the difference between treatment groups is small, a multicentre study of large patient groups will be required to further determine the optimal form of treatment for closed fractures of the tibial shaft.

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