TIBIAL SHAFT FRACTURES TREATED WITH FUNCTIONAL BRACES

EXPERIENCE WITH 780 FRACTURES

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We have reviewed our recent results with functional bracing of tibial shaft fractures in adults in order to define its role in management. We also analysed several parameters of these fractures to discover those which influence healing. A total of 780 tibial fractures treated in prefabricated functional braces were followed to union; shortening of less than 10 mm and angulation of less than 5° in any plane were our parameters for successful treatment.

The average time before applying a brace was 3.8 weeks for closed fractures and 5.2 weeks for open ones. Closed fractures healed in an average of 17.4 weeks and open fractures in an average of 21.7 weeks, 90% of them with 10 mm of shortening or less. Varus angulation and posterior angulation were the most common deformities encountered at union. There were 20 nonunions (2.5%) and 46 braces were discontinued during treatment. We found no association between fracture healing and the patient's age, the mechanism of injury or the fracture location.

The degree of soft tissue injury appeared to have most influence on the speed of fracture healing. Fracture comminution and initial displacement, the condition of the fibula and the time from injury to bracing also appeared to affect the speed of union.

The goal of treatment of fractures of the tibial shaft in adults is to restore anatomy and to regain function as quickly as possible. To achieve this, many treatment protocols have been described: closed reduction and immobilisation, closed reduction and early function (Dehne et al 1961a; Sarmiento 1967, 1970; Brown and Urbin 1969; Burkhalter and Protzman 1975), rigid intramedullary nailing (Bone and Johnson 1986; Puno et al 1986), flexible Enders nailing (Mayer et al 1985; Wiss 1986), compression plating or interfragmentary screwing (Jensen, Hansen and Johansen 1977; van der Linden and Larsson 1979; Johner and Wruhs 1983) and external fixation. The treatment and prognosis of each fracture is influenced by many factors, most notably the degree of soft tissue damage at the fracture site, the extent of comminution and the associated injuries sustained in the same accident (Ellis 1958; Nicoll 1964; Johner and Wruhs 1983).

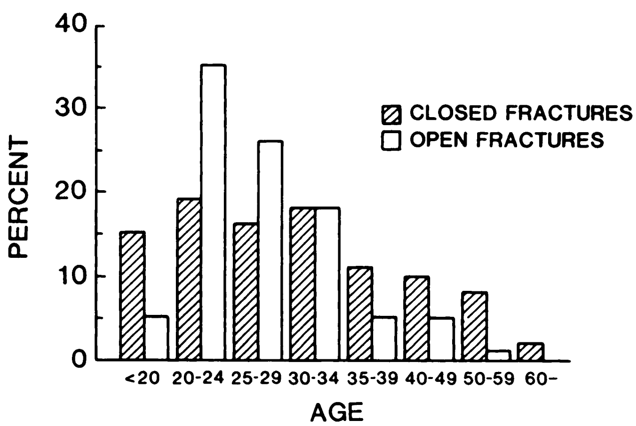

Fig. 1

Age distribution of 780 tibial shaft fractures treated by functional bracing.

Experience over 20 years has demonstrated that functional bracing is an effective form of management for selected fractures of the tibial shaft (Sarmiento 1970; Sarmiento and Latta 1981; Zych et al 1987; Ekkernkamp

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0301-620X/89/4122 $2.00
J Bone Joint Surg [Br] 1989;71-B:602-9.

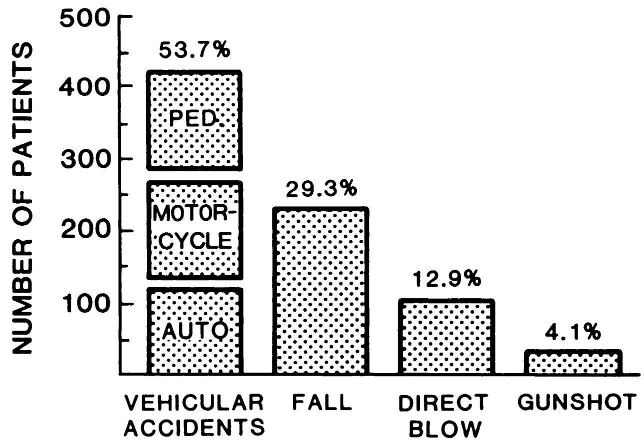

Fig. 2

Mechanism of injury in 780 tibial fractures.

et al 1985). The principle of functional bracing is based upon the belief that controlled motion at the fracture site is conducive to osteogenesis (Sarmiento et al 1977; Sarmiento and Latta 1981; Sarmiento et al 1984). A small amount of angulation and shortening may be accepted in an attempt to restore early function and obtain rapid healing.

Recently, more aggressive approaches have been applied to the patient with multiple injuries and to fractures resulting from high energy trauma. Early stabilisation, aggressive debridement and the use of soft tissue flaps have improved the outcome of these injuries (Wiss 1986).

Our study has reviewed the recent results of functional bracing of tibial shaft fractures in adults in order to define its role in management. By studying a large number of fractures we have been able to assess those factors which may influence the rate of healing.

MATERIALS AND METHODS

From January 1979 to December 1985, 1 242 fractures of the tibial shaft, in skeletally-mature patients, were treated in prefabricated functional braces at the University of Southern California Medical Center. Of these, 780 fractures (63%) were followed to clinical and radiographic union, while 46 (4%) required the brace to be discontinued and 20 (2.5%) failed to unite. Of the 396 fractures not included in this study (31%), 173 cases (14%) presented to us later than 12 weeks after injury, and 223 (17%) were lost to follow-up.

There were 610 men (78%) and 170 women. The average age of the patient was 30 years (range 15 to 74 years). As expected, most open fractures were seen in younger patients, while those with closed injuries were relatively evenly distributed between the ages of 20 and 50 years (Fig. 1).

A vehicular accident was the most common cause of injury (Fig. 2), and low-energy trauma was responsible for most of the others. In all, 539 fractures (69%) were closed and 241 (31%) were open. Using Gustilo's classification of open fractures (Gustilo and Anderson 1976), there were 78 grade I (32%), 97 grade II (40%), and 34 grade III (14%). Of these fractures, 32 (14%) resulted from gunshot wounds.

Eighty-six fractures (11%) involved the proximal third of the tibia, 330 (43%) the middle third, 339 (44%) the distal third and 25 (3%) were segmental. There were 145 (19%) transverse fractures, 214 (27%) oblique, 158 (20%) spiral, 238 (31%) comminuted and 25 (3%) segmental. Associated fibular fractures appeared in 595 (76%) while 185 cases (24%) involved only the tibia.

In 140 patients (18%) associated injuries including trauma to the head and neck, abdomen, lacerations and fractures involving the skull, upper limbs or the contralateral leg were reported. Four patients had bilateral tibial fractures. No injury was severe enough to prevent walking after stabilisation.

Our indications for the use of a prefabricated functional brace included most closed and many open fractures with minimal soft tissue damage. Fractures treated with external fixators were converted to a prefabricated functional brace as soon as they had developed intrinsic stability. Bracing was used only for ambulatory patients.

Contra-indications for bracing included fractures with excessive initial shortening and fractures which showed increasing angular deformity in the initial cast. Shortening of less than 10 mm and angulation of less than 5° in any plane were our treatment parameters. Patients with significant neurological or vascular damage, with segmental bone loss and those requiring soft tissue flaps were not braced.

The majority of our patients were initially treated in, and subsequently referred from, our emergency room. The remaining patients received their initial care elsewhere and were referred to us for follow-up. We treated many other tibial fractures surgically; these do not constitute part of this report. Many patients involved in high-energy accidents with multiple injuries and those with an ipsilateral femoral fracture were often managed by immediate operative stabilisation of their fractures.

Patients with closed fractures requiring manipulation were reduced under regional anaesthesia and a long-leg cast applied. Those not requiring manipulation had the long-leg cast applied under sedation. Care was taken to place the ankle in neutral position. If the length and alignment were acceptable, a prefabricated functional brace was applied when the initial pain and swelling had subsided. The patient was instructed to bear weight on his injured extremity when tolerable. Active movement of the knee and ankle were encouraged. The patient was taught how to remove the brace for sock changes and wound care, when indicated, beginning one week after its application.

Open fractures were initially treated with irrigation and debridement followed by application of a long-leg cast if the soft tissue cover was adequate. Otherwise an external fixator was applied. Intravenous antibiotics, a cephalosporin and an aminoglycoside, were administered for 72 hours. The leg was placed in a prefabricated functional brace as soon as the soft tissue wounds were stable.

Grade III open fractures were treated by external fixation. Providing adequate wound healing was obtained and the fracture was thought to be reasonably stable, the fixator was removed at six weeks, and the leg placed in a below-knee functional cast for one week to allow the pin sites to heal. A prefabricated functional brace was then applied.

Patients were reviewed at monthly intervals. Anteroposterior and lateral radiographs including both the knee and ankle were taken at each visit. Measurements of shortening, varus/valgus and anterior/posterior angulation were made on each set of films. Loss of acceptable alignment necessitated remanipulation of the fracture or adjustment of the brace. If clinical and radiographic studies indicated that the fracture was not being held in the desired alignment, the brace was discontinued and a different line of treatment followed. The involved leg was examined for pressure sores or wound drainage and, if required, braces were temporarily discontinued and casts re-applied to allow further wound healing. Union was defined as the time when bridging callus was identified on radiographs and the fracture site was painless during full weight-bearing. The brace was then discontinued.

RESULTS

Bracing. The average time to application of the prefabricated functional brace after injury was 3.8 weeks for closed fractures (6 days to 12 weeks) and 5.2 weeks for open fractures (7 days to 12 weeks). Fractures involving the proximal third of the tibia and segmental fractures required the longest periods of immobilisation, 4.9 and 4.8 weeks, respectively. Comminuted fractures required a longer delay than other closed fractures before bracing (5.2 weeks). Open grade I fractures and fractures secondary to gunshot wounds were braced at approximately the same time as closed fractures. Open grade II and III fractures required substantially longer periods in casts before bracing.

Healing. Fractures were considered to have healed on the date that the braces were finally removed. The average time to union for all fractures treated in a prefabricated functional brace was 18.7 weeks (range 6 to 40 weeks). Closed fractures healed in an average of 17.4 weeks (6 to 39 weeks) and open fractures in an average of 21.7 weeks (6.5 to 40 weeks). Open grade I fractures and fractures resulting from gunshot wounds healed in a comparable time to closed fractures, 18.3 and 17.5 weeks, respectively. Open grade II and III fractures required approximately seven weeks longer to unite (Fig. 3a).

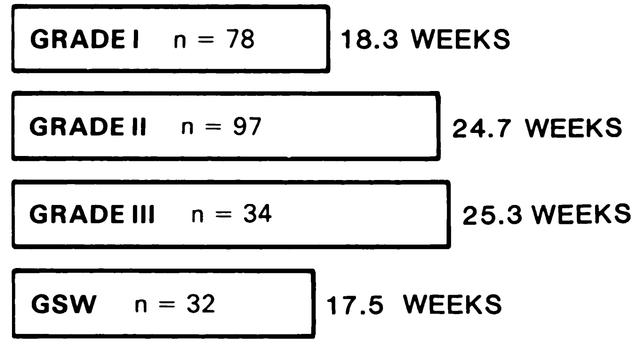

Fig. 3a

Time from injury to union in 241 open tibial fractures according to Gustilo grade of soft tissue injury. GSW, gunshot wound.

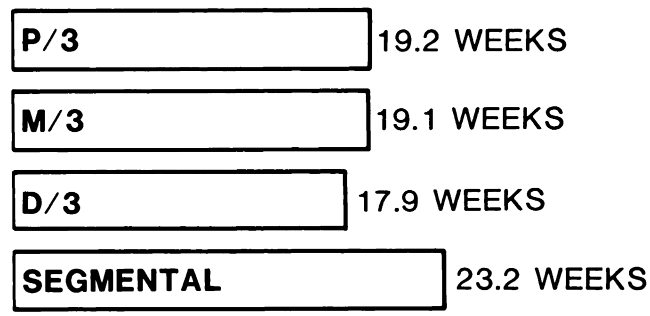

Fig. 3b

Time from injury to union according to level of fracture. P, proximal; M, middle; D, distal thirds.

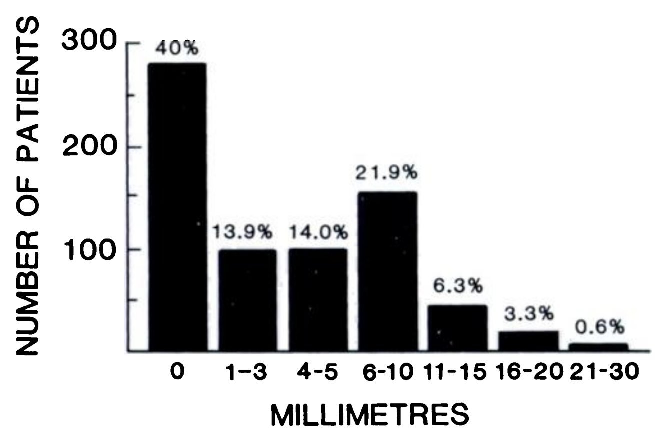

Fig. 4

Shortening at union in 780 tibial shaft fractures.

The site of the fracture did not affect healing, but segmental fractures required approximately one month longer to unite (Fig. 3b). The presence of an intact fibula influenced fracture healing. Isolated tibial fractures healed in 17.5 weeks (7 to 36 weeks) whereas fractures of both tibia and fibula healed in 21.5 weeks (7 to 40 weeks). Patients placed in functional braces during the first six weeks after injury healed significantly faster than those in patients who were braced after that time. In the 611 fractures (78%) that were braced prior to six weeks,

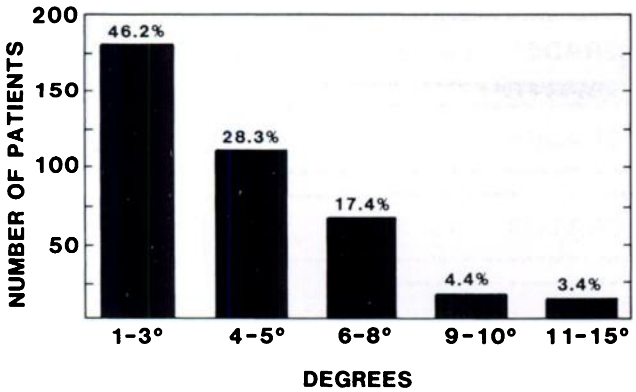

Fig. 5a

Varus angulation at union in 385 fractures (49% of series).

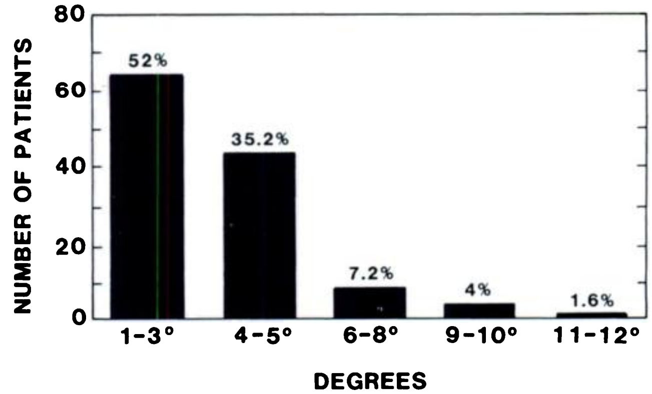

Fig. 5b

Valgus angulation at union in 125 fractures (16% of series).

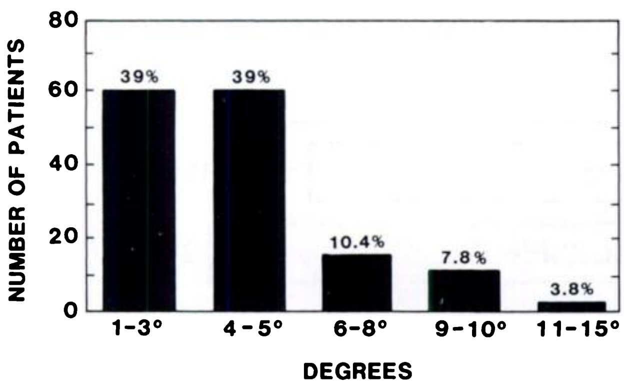

Fig. 5c

Anterior angulation at union in 154 fractures (20% of series).

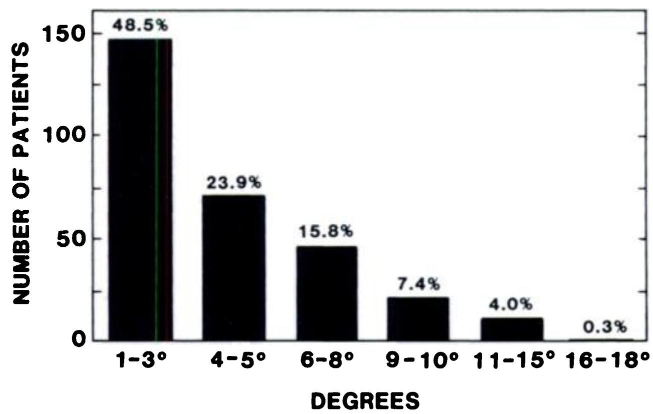

Fig. 5d

Posterior angulation at union in 297 fractures (38% of series).

healing occurred in an average of 17.3 weeks (range 7 to 40 weeks). The 169 fractures (22%) placed in a brace later than six weeks healed in an average of 22.1 weeks (range 10 to 42 weeks). Included in this second category are the 73 patients (9%) who were initially treated with an external fixator. Their time to bracing averaged 7.1 weeks (range 1 to 12 weeks) and the time to union averaged 26.8 weeks (range 13 to 42 weeks).

Shortening. On final radiographic assessment, 312 fractures (40%) healed without shortening, 468 (60%) with an average shortening of 7.1 mm (1 to 31 mm); 700 fractures (90%) healed with 10 mm of shortening or less. There were 21 fractures (3%) that healed with more shortening than was documented on the initial radiograph; this averaged 4 mm (1 to 8 mm) (Fig. 4).

Angulation. A total of 385 fractures (49%) healed with varus angulation (1° to 15°). Of these 289 (75%) healed with 5° of varus angulation or less. Twelve patients demonstrated 11° of varus or more (Fig. 5a). Of the patients with an isolated tibia fracture, 96 (52%) healed with an average varus angulation of 4° (1° to 12°). In this group, fractures of the proximal and distal thirds of the tibia showed the greatest angulation, 6.5° and 6.0° respectively while fractures of the middle third healed with an average of 3.9° of varus. There were 125 fractures (16%) that healed with valgus angulation (1° to 12°). Of these 110 (88%) healed with 5° of valgus or less and three (2%) demonstrated more than 10° of deformity (Fig. 5b).

Healing occurred in 154 fractures (20%) with anterior angulation (1° to 15°), 120 (78%) with less than 6° and six (4%) with greater than 10° of angulation (Fig. 5c). Posterior angulation of 1° to 18° showed in 297 fractures (38%), 214 (72%) with 5° of angulation or less and 12 (4%) with 11° or more (Fig. 5d).

Malrotation. Attempts to determine the incidence of rotational deformity proved unsuccessful because no reliable method of determination was developed until late in the series. It is our belief, however, that this complication is rare and not likely to develop following the application of a brace. Rotational deformities not corrected at the time of the initial reduction and casting tend to persist.

Complications. Any fracture which failed to unite within 12 months of injury was classified as a nonunion. There were 20 cases of nonunion (2.5%) in our series, with an average age of 34 years (22 to 54 years), and 18 (90%) of these were the result of a vehicular accident. There were 16 open fractures (80%), three grade I, six grade II, six grade III and one caused by a gunshot wound. Eighteen fractures had an associated fibular fracture, and 14 cases were initially treated by closed reduction and application of a long-leg cast. Six cases were treated with an external fixator. A fibular osteotomy was performed in two cases, one at two weeks post-injury in a patient with an intact fibula and one at six months in a patient with a transverse middle third fracture and an associated fibular fracture which had already united.

During treatment 46 braces were discontinued; 11 (24%) removals were due to progressive angulation and four (9%) to loss of corrected shortening. These patients were advised to undergo an operation to correct their deformity. Fourteen of these 46 patients (31%) could not wear their brace due to irritation of pre-existing soft tissue wounds and were treated in below-knee functional casts until union. One elderly patient fell, displacing her tibial fracture, and 16 patients (37%) were unable to manage the functional brace. These patients were treated in below-knee functional casts until union.

After the prefabricated brace had been applied 25 cases (3%) required remanipulation of the fracture. This was performed with the patient sitting and flexing his leg over the edge of the examining table. The manipulation was done under sedation. In these cases, the braces were temporarily discontinued for two to six weeks and long-leg casts were applied. Fifteen braces (2%) were temporarily discontinued because of excessive wound drainage. Drainage soaking more than one gauze pad per day was considered excessive and the extremity was placed in a more absorbent plaster below-knee cast until the wound had healed. None of these wounds required surgical debridement.

Skin problems included 20 cases of skin maceration under the brace, 10 abrasions over the malleoli and one full thickness skin loss from pressure over a medial pad that had been placed inside the brace. Bracing adjustments and contouring were performed when necessary to ensure proper fitting. The only case of osteomyelitis occurred in an open fracture that went on to develop nonunion.

Healing parameters. During the past years we have taken a more aggressive surgical approach to the treatment of open fractures and markedly unstable closed fractures of the tibial shaft. While the number of our patients treated by functional bracing has remained constant, the characteristics of the fractures and the soft tissue wounds have changed. In the second half of the whole series, 392 fractures were analysed according to fracture type, location, initial displacement, comminution, mechanism of injury, condition of the fibula and time to bracing, so as to identify the characteristics which influence fracture healing and prognosis.

There was no association between the patient's age and fracture healing either in closed or open fractures (Fig. 6). Closed isolated tibial fractures required the shortest time to heal, 14.4 weeks, and grade III open fractures required the longest, 24.9 weeks, nearly two months longer than any other fracture group. The rate of healing was similar for all fracture groups except open grade III fractures which demonstrated a high percentage of delayed union. Of these fractures, 64% required more than 20 weeks to unite.

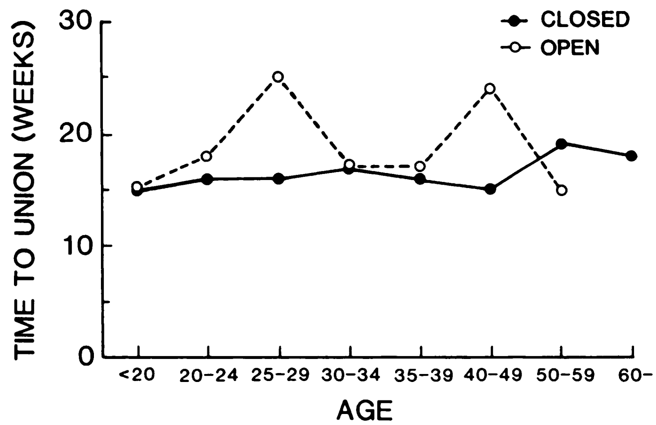

Fig. 6

Age related to time to union.

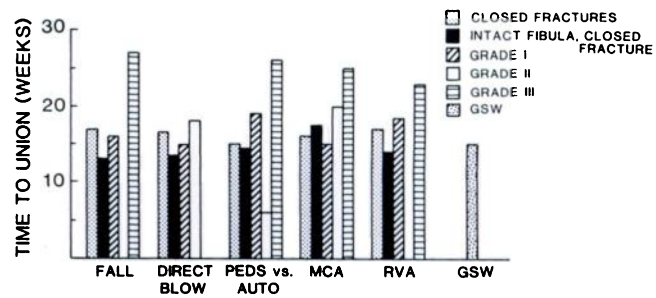

Fig. 7

Mechanism of injury related to time to union.

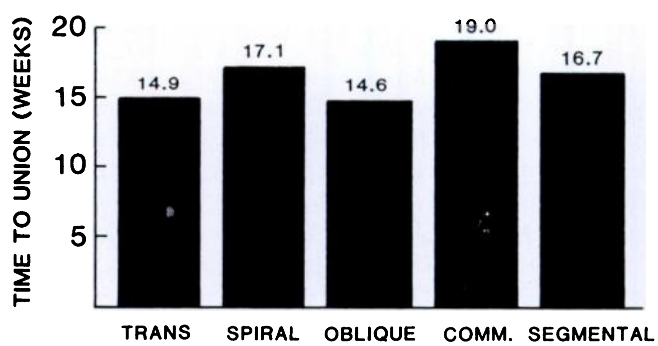

Fig. 8

Type of fracture related to time to union.

There was no difference in the time to union for any fracture group in relation to the mechanism of injury. Low energy injuries including short distance falls, direct blows and low-velocity gunshot wounds, healed in similar fashion to fractures caused by high-energy motor vehicle accidents; this applied to both closed and open fractures (Fig. 7).

Comminuted fractures required the longest time to

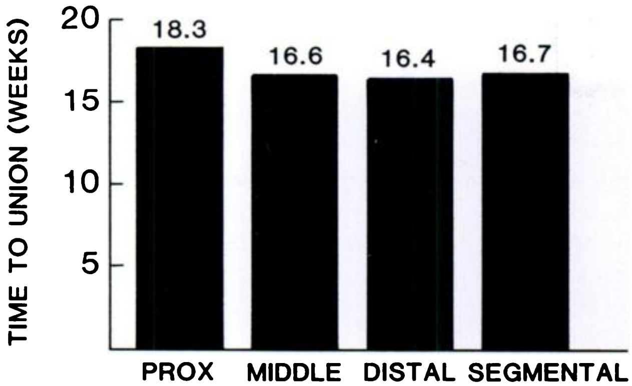

Fig. 9

Level of fracture related to time to union.

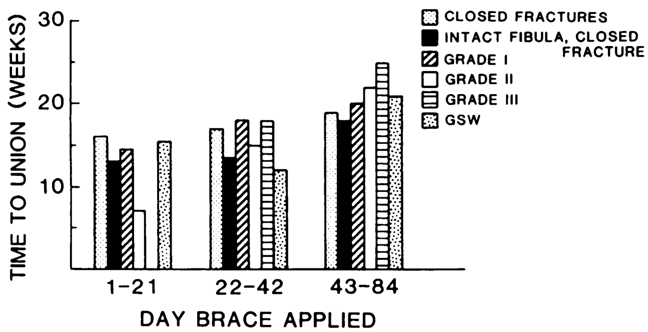

Fig. 10

Time between injury and application of brace related to time to union.

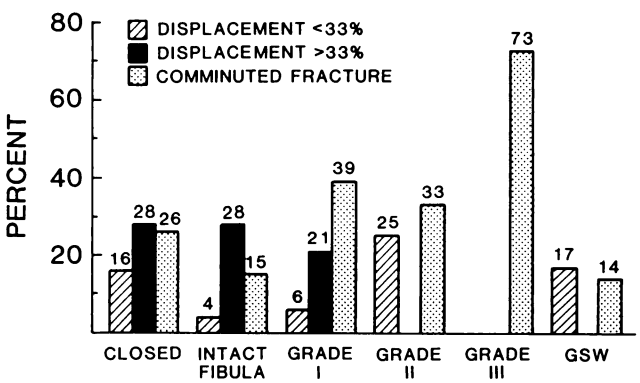

Fig. 11

Incidence of delayed union (over 20 weeks) related to displacement and type and severity of fracture.

unite (19 weeks) except for open grade II fractures and fractures secondary to gunshot wounds. Comminuted open grade III fractures were the slowest to unite averaging 27.3 weeks. Transverse and oblique fractures healed in the shortest time, 14.9 and 14.6 weeks respectively while spiral and segmental fractures required approximately 17 weeks to heal (Fig. 8). Fractures in the proximal third of the tibia required one additional week to unite when compared to other locations (Fig. 9).

The condition of the fibula appeared to influence the healing of the tibial fracture. Isolated tibial fractures healed in an average of 14.4 weeks. A tibial fracture with an associated fibular fracture at the same or at a different level healed at 17.8 and 17.4 weeks respectively.

The interval between injury and bracing, the amount of initial displacement and the degree of comminution reflected differences in the time to union for each group. For all patients, when the functional brace was applied within the first three weeks of injury, healing occurred in an average of 15.4 weeks. Union was delayed almost six weeks when the brace was applied later than six weeks after injury. This increase of 25% to 50% was seen in all groups of fractures (Fig. 10).

Initial displacement of over one-third of the tibial shaft diameter was associated with prolonged healing times except for fractures secondary to gunshot wounds. Non-displaced and minimally displaced fractures demonstrated no difference in healing times, while moderate displacement (34% to 67%) and severely displaced fractures (68% to 100%) required approximately the same time to heal (Fig. 11). Initial displacement was not documented for open grade III fractures because many had manipulations before the initial radiograph was taken.

Comminution was associated with an increased incidence of delayed union for all fracture groups except closed tibial fractures with an intact fibula and those secondary to gunshot wounds. One-third of the comminuted closed, open grade I and grade II fractures resulted in a delayed union. Of all comminuted open grade III fractures, 78% required more than 20 weeks to unite. Neither comminution nor initial displacement appeared to influence the rate of union for fractures secondary to gunshot wounds.

DISCUSSION

The concept of early weight-bearing for the treatment of tibial shaft fractures was popularised in the United States over 40 years ago. Dehne et al (1961a,b) working with injured military personnel, found that both the time to union and the number of complications decreased when early weight-bearing was encouraged after closed reduction and cast immobilisation. Brown and Urbin (1969) and Burkhalter and Protzman (1975) employed the same technique for the treatment of both closed and open tibial fractures and demonstrated similar results. One of us (AS) developed the functional below-knee cast and later the custom made prefabricated functional brace, and suggested the contribution of controlled motion to fracture healing (Sarmiento 1967, 1970; Sarmiento et al 1974; Sarmiento et al 1977; Sarmiento et al 1984).

Success with the use of functional bracing is dependent upon a clear understanding of its principles and rigid adherence to technical details. The extent of injury to the soft tissues surrounding the fracture site provides the key to fracture alignment and healing (Sarmiento et al 1974; Latta, Sarmiento and Tarr 1980). Closed fractures exhibit their maximum shortening at the time of injury. Angulation at the fracture site is prevented by the encasement of the soft tissues around the fracture by the brace (Sarmiento et al 1974; Latta et al 1980). Shortening is determined by the degree of initial soft tissue damage and is not affected by bracing.

Controlled motion at the fracture site has been shown to create physiological conditions which are conducive to osteogenesis (Sarmiento et al 1974; Sarmiento et al 1977; Sarmiento and Latta 1981). Functional treatment does not violate the fracture site; it allows early vascular regeneration and eliminates further damage to the intramedullary and peripheral blood supply which occurs during intramedullary reaming or compression plating. In our series a functional brace was applied within the first month after injury for the majority of patients and early motion seemed to lead to more rapid callus formation and to avoid joint stiffness and muscular atrophy (Sarmiento et al 1977).

In the literature the average time to union for fractures of the tibial shaft is difficult to establish since an adequate definition of fracture healing has not been agreed. Nonoperative treatment allows abundant callus formation and easy detection of bridging callus (Sarmiento et al 1977; McKibbin 1978; Latta et al 1980; Sarmiento and Latta 1981). The goal of operative treatment is primary bone healing without peripheral callus. The stability of internal fixation impairs an adequate estimation of fracture healing. Sarmiento (1967, 1970), Sarmiento et al (1984), van der Linden and Larsson (1979) and Puno et al (1986) have all reported fracture healing times of between 16.9 and 20 weeks following nonoperative treatment. Time to union following AO plating (Edwards 1965; Johner and Wruhs 1983), intramedullary nailing (Bone and Johnson 1986) and Enders nailing (Wiss 1986) have been reported to be between 10.8 and 19 weeks. Jensen et al (1977) compared plating to casting and found that transverse fractures healed three weeks earlier when treated in a cast, and oblique and comminuted fractures healed four to six weeks earlier than after open reduction and internal fixation.

In our whole series we found union in an average of 18.7 weeks, suggesting the beneficial effects of a physiological environment in fracture repair. Significantly, closed fractures, open grade I fractures and fractures secondary to gunshot wounds all gave similar results.

We accept minor losses in length and alignment of the tibia as small sacrifices in an effort to provide early function and decreased morbidity. These minor defects are easily compensated for and do not represent functional or cosmetic disturbances. Wagner et al (1984) using cadaver limbs, have demonstrated that the changes in stress patterns at the tibiotalar joint are not significant with angulatory deformities less than 10° in any plane. Posterior angulation in the distal third of the tibia created the most significant pressure alterations.

Fractures of the tibia with an intact fibula require close observation during treatment. These fractures are prone to drift into varus as the fractured tibia moves toward the fibula (Sarmiento and Latta 1981). Our experience revealed that fractures of the proximal third of the tibia demonstrated the greatest varus deformity, 6.5°. When the angulatory deformity could not be prevented, an osteotomy of the fibula was performed at the level of the fracture site to allow fibular shortening and relieve the varus stress on the tibia. Teitz, Carter and Frankel (1980) have reported an increased incidence of osteoarthritis at the ankle of patients with healed isolated tibial fractures. This has not been our experience.

An advantage of nonoperative treatment of tibial fractures has been the low incidence of nonunion and infection. None of our closed fractures developed an infection. Our overall rate of nonunion was 2.5%, 0.7% in closed fractures and 6.6% in open fractures. In our series of open fractures, there was a three to fivefold increase in the nonunion rate for open grade III fractures (17.6%), compared with grade II (6.2%), grade I (3.8%) and fractures secondary to gunshot wounds (3.1%). Fractures initially treated in an external fixator exhibited an incidence of nonunion of 8.2%. This significant increase in the nonunion rate associated with open fractures and grade III fractures in particular, is reflected in the literature (Rosenthal, MacPhail and Ortiz 1977).

The prognosis of fractures of the tibial shaft has been related to many factors, most directly with the severity of the soft tissue damage rather than the bony injury (Bauer, Edwards and Widmark 1962; Edwards 1965; Johner and Wruhs 1983). Bauer et al (1962) related a low-energy injury (for example, a fall or sporting accident) to a good prognosis. Johner and Wruhs (1983) used the mechanism of injury and the degree of comminution, soft tissue injury and displacement as guides to fracture outcome. Fractures caused by indirect trauma, identified by a spiral fracture pattern, had a better prognosis than those associated with direct trauma. Nicoll (1964) in a study of 705 fractures, 674 of which were treated closed, identified displacement, comminution and soft tissue wounds as the three factors which influenced fracture healing. Ellis (1958) took these same three factors and created an injury severity score: the greater the displacement and soft tissue injury the higher the score; comminuted fractures were placed in the highest category. He found these parameters to be the major determinants of the speed of fracture healing.

Our study found no association between fracture healing and the patient's age, the location of the fracture or the mechanism of injury, but identified the amount of soft tissue injury to be the most important factor regardless of the mechanism of injury. Initial fracture displacement, comminution, the condition of the fibula and the time to bracing all contributed to the rate of fracture healing.

It is interesting to consider the impact of the condition of the fibula on fracture healing. Both Rosenthal et al (1977) and Nicoll (1964) identified a decreased incidence of delayed union when the fibula was intact. Nicoll found that the intact fibula gave the tibia stability and minimised the amount of tibial displacement. Other authors have associated an isolated tibial fracture with a low-energy injury (Dehne et al 1961b; Rosenthal et al 1977). In our series, closed tibial fractures with an intact fibula healed in the shortest amount of time (14.4 weeks). Again, in each category examined, these fractures constantly demonstrated a rapid time to union and a decreased incidence of delayed union.

In all fracture-groups studied, closed fractures of both bones, closed fractures with an intact fibula, open grade I fractures and fractures secondary to gunshot wounds, behaved in a similar fashion. Open grade III fractures demonstrated prolonged times to bracing and fracture healing in each category examined. Displacement greater than one-third of the tibial shaft diameter and fracture comminution appeared to affect the rate of fracture healing and the incidence of delayed union.

The introduction of functional bracing appeared to influence fracture healing positively. Each fracture group, except those secondary to gunshot wounds, demonstrated prolonged times to union as bracing was initiated further from the date of injury. The severity of the injury appeared to influence this outcome as the time to union for closed fractures exhibited the least amount of change when bracing was delayed.

Our experience indicates that prefabricated functional braces are an acceptable form of treatment for selected tibial shaft fractures. Many closed and open fractures with minimal soft tissue damage may be treated with a predictable outcome as regards shortening and alignment. In over 25 years of observation, small amounts of shortening and angulation have not been associated with osteoarthritis or diminished function at a later date and are cosmetically acceptable to the patient.

A significant observation from this study is the recognition of the condition of the soft tissues as the major factor influencing fracture healing. All closed fractures and open grade I fractures should be considered together when discussing rates of fracture union. Open grade III fractures should be classified as partial amputations and require aggressive treatment; very few are suitable for bracing.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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