PLATE FIXATION OF TIBIAL SHAFT FRACTURES

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ABSTRACT: The treatment of tibial shaft fractures is discussed with emphasis given to plate and screw fixation. A review of plate fixation of 65 tibial fractures is presented with average followup of 4.37 years. When reserved for unstable fractures with minor soft tissue disruption, internal fixation by the use of plates and screws resulted in a small incidence of deformity and shortening, with little risk of local complications. Comparison of our incidence of complications with those previously published illustrate that serious complications are mainly a result of the type and severity of the initial trauma. Some technical considerations are briefly discussed. Recommendations are proposed for the treatment of the various types of tibial shaft fractures.

Introduction

The management of tibial shaft fractures remains a highly controversial subject. Previous workers have discussed various methods of treatment, including long leg cast immobilization with an extended or a flexed knee (Dehne, Witschi, Burkhalter, Nicole), functional bracing (Sarmiento, Dehne), skeletal traction (Apley, Watson Jones), open reduction with internal fixation (Karlstrom, Jensen, Burwell, Muller, Burny), and external fixation (Burny). Many of these studies attempted to use a single method for the management of a great variety of open and closed tibial shaft fractures. A recent paper by Van der Linden indicated that either plate fixation or cast immobilization might be randomly selected as the method of treatment for all displaced, open or closed tibial fractures.

With the available knowledge, it seems evident that many fractures amongst this vast spectrum of injuries require the use of a particular therapeutic regime, and could be unfavorably influenced by the random application of many other modalities of treatment. In the presence of a closed, undisplaced, transverse, midshaft fracture, a cast or cast brace immobilization would appear to have few rivals. Alternatively, for the Grade III open fracture sustained as a bumper injury and accompanied by a 12 cm segmental bone loss, external fixation would appear to be the optimum therapeutic method that might facilitate salvage of the limb. To us, it seems that even within the limitations of our present knowledge, such selection of therapeutic techniques is essential, and that present and future work is needed to define the limits of a fracture type where a particular method of treatment is optimal, suitable or contraindicated.

With this concept in mind, we have reviewed the results of operative treatment of 65 tibial shaft fractures. In all of the cases the fibula also was fractured. Rigid internal fixation achieved by the use of a plate and screws was selected for certain tibial shaft fractures where cast immobilization had failed.
Historically, this series was undertaken before, during and after the AO experience, which provoked considerable alterations in the operative techniques and the surgical implants. Many of the complications encountered here enlightened us and are shared in this paper.

**Materials and Methods**

Sixty-five fractures of the tibial shaft with accompanying fibular fractures in 64 patients were included in the study. The patients treated between 1961 and 1978 were studied in the following hospitals: St. Francis Hospital, Poughkeepsie, New York; Vassar Hospital, Poughkeepsie, New York; Presbyterian University Hospital, University of Pittsburgh, Pittsburgh, Pennsylvania. The ages of the patients ranged from 14 to 77 years. Clinical records of all 64 patients, as well as radiographs from 1970 to the present were reviewed. Thirty-six patients (55%) were located and returned questionnaires; 23 of these patients (28%) had followup examinations. Every patient was followed until clinical and radiographic union were documented. This followup period varied between six months and 18 years, with an average of 4.37 years. The distribution according to sex revealed 65% men (42 patients) and 35% women (22 patients). The fractures are summarized according to fracture pattern in Table 1. All patients who sustained an open fracture or who underwent an open reduction of a closed fracture were given systemic antibiotics, usually for a period of 48 hours: At surgery the soft tissues were handled with extreme gentleness.

During the period of this study, numerically most of the tibial fractures presented to us were treated nonoperatively. This report, however, focuses upon the fractures that were managed operatively as depicted in Table 2.

A preliminary attempt was made to stabilize most of the fractures with a long leg cast. If adequate reduction could not be maintained—or alternatively, if clinical and radiologic features of the injury suggested that cast immobilization would not provide adequate stability—another method of treatment was employed. Most of the fractures in this study consisted of comminuted fractures with less than five to ten major fracture fragments. For this group, which is the subject of this report, the principal method employed was internal fixation with the use of an onlay plate and, frequently, ancillary lag screws.

Prior to 1967, ancillary postoperative cast immobilization following plate fixation was performed routinely for a variable period of time. After 1967, the use

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**TABLE 1**

**FRACTURE PATTERNS**

<table>
<thead>
<tr>
<th>Level of Fracture</th>
<th># Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal third</td>
<td>17</td>
</tr>
<tr>
<td>Junction middle and distal third</td>
<td>24</td>
</tr>
<tr>
<td>Middle third</td>
<td>22</td>
</tr>
<tr>
<td>Junction middle and proximal third</td>
<td>1</td>
</tr>
<tr>
<td>Proximal third</td>
<td>0</td>
</tr>
</tbody>
</table>

**TABLE 2**

**FRACTURES MANAGED OPERATIVELY**

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Plate Fixation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed</td>
<td>45</td>
</tr>
<tr>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>Grade I</td>
<td>8</td>
</tr>
<tr>
<td>Grade II</td>
<td>4</td>
</tr>
<tr>
<td>Grade III</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>65</td>
</tr>
</tbody>
</table>

**CLASSIFICATION OF OPEN FRACTURES**

- **Grade I** Puncture wounds “from within” or small lacerations up to 2.5 cm long. No loss of skin or significant muscle damage.
- **Grade II** Wounds larger than 2.5 cm with soft tissue contusion. Safe closure is possible.
- **Grade III** Severe crush injuries, extensive damage to skin & muscles. Primary closure is difficult or impossible.

*Fig. 1*

or where it was anticipated that it would fail. To us, failure of closed treatment with cast immobilization refers to an anticipated delayed union, nonunion or malunion with significant rotational or angular deformity or shortening greater than 2 cm. In the more recent period of study, patients with Grade III fractures, especially those with bumper injuries, overwhelming contamination, and marked comminution with greater than five to ten osseous fragments or with segmental bone loss would be managed by external fixation primarily by the use of a Hoffmann device.‡

‡Howmedica Inc., Rutherford, New Jersey
of postoperative cast immobilization was reserved for use in situations where the surgical stabilization was tenuous or where the reliability of the patient was questionable.

**Results**

Sixty-five fractures were treated operatively by the use of plate fixation. Of this group, 45 cases were closed fractures and 20 were open injuries. Of the latter, eight were Grade I, four were Grade II, and eight were Grade III open injuries (Fig. 1). Out of this group, 52 fractures (80% of cases) united uneventfully within a period of eight months. Thirteen patients (20% of cases) sustained one or more problems or complications:

- **Infection.** Deep wound infection was documented in two cases (3%). One case was a Grade III open injury in which the plate fixation facilitated salvage of the limb.
The other case (Fig. 2) was a closed football injury sustained by a juvenile diabetic. Both cases progressed to a nonunion and required further operative procedures. Ultimately, after many months both cases united and ceased to drain.

- **Nonunion.** Four nonunions (6.1%) were recorded, of which two cases presented in the patients who developed wound infections following internal fixation. A third case was a motorcyclist with a Grade III open fracture. The fourth case was a low velocity injury that demonstrates improper application of a plate with distraction of the fracture fragments. It progressed to a nonunion (Fig. 3).

- **Malunion.** Two cases (3%) of malunion were documented. Both were associated with implant failure (Fig. 4).

- **Implant Failure.** Two cases (3%) underwent mechanical failure of a plate. One patient, an alcoholic, undertook a full weight gait against medical advice. The second case (Fig. 4) occurred in a patient who sustained bilateral tibial fractures and also undertook a full weight bearing gait. Both implants failed at approximately four to five months after surgery.

- **Shortening.** Two cases with shortening of 2 cm or greater were documented. One occurred in an infected nonunion (2 cm) and the other occurred in a Grade III open injury (4.5 cm).
removal of the implants. The latter two cases were sustained upon return to active skiing (Fig. 5). A fourth case of refracture (Fig. 6) was recorded in a T12 motor sensory level paraplegic with accompanying tibial fracture.

**Discussion**

Previous workers have attempted to correlate patterns of tibial fractures with the prognosis for uneventful healing. Nicole believed that the magnitude of the displacement of the fracture is an important prognostic factor. Burwell and Veliskakis emphasized the sinister influence of soft tissue disruption adjacent to a tibial shaft fracture. In addition, these workers implicated the complexity of the fracture and degree of comminution. Clearly all of these factors are important. When conventional methods of closed treatment are applied to such complex fractures, a high incidence of problems or complications can be anticipated.

The fractures which ensue from high velocity accidents are those in which a large amount of kinetic energy is dissipated rapidly at the fracture site. Generally they require some form of surgical stabilization. Those fractures which arise by the most violent forces and present as Grade III open fractures usually merit consideration for external fixation. Nevertheless, the fractures deserving consideration for open reduction and internal fixation generally follow a dissipation of kinetic energy upon the limb which is much greater than that which provokes a typical closed and potentially stable tibial shaft fracture. It is this intermediate group of fractures, provoked by moderately severe energy dissipation, which constitutes the principal source of fractures documented in this report. In most of these examples, closed methods of treatment were not employed or were abandoned because they possessed an unacceptably high incidence of anticipated failures, especially malunion and delayed or nonunion. For example, Fig. 7 represents an open Grade I injury, which exhibits moderate comminution, instability and soft tissue disruption. Immediate postoperative fixation culminated uneventfully in an anatomic union, full joint motion and good soft tissue healing.

A short discussion regarding our complications is indicated. Many of the fractures that sustained one complication also sustained other allied complications. This factor inflates the number of complications and the overall incidence reported. Our overall incidence of major complications, i.e., nonunion and infection, is 6%. More minor complications including malunion,
Implant failure, refractures and joint stiffness constitute 14% for a total incidence of 20%. This complication rate reflects the consolidation of the various tibial fractures, both the open and the closed injuries, which possess markedly different prognoses.

Infection presents the most serious complication to beset a healing fracture. In most studies, internal fixation applied to a closed fracture is felt to add slightly to the incidence of infection (1-4%). \(^{12,13,121-123}\) However, the incidence of infection for open fractures treated with nonoperative stabilization has been reported between 6% and 17% \(^{12,13,121-123}\) as opposed to incidences varying between 3% and 11% when techniques of rigid internal fixation are employed. \(^{12,13,121-123}\) The rigid stabilization seems to provide a superior environment for the restoration of the adjacent soft tissues. In our study, both deep infections culminated in nonunions. One was a Grade III injury that at present would be treated by the application of external fixation. The other, a closed fracture, represents one infection in 45 closed fractures that were managed by the use of an internal compression plate, an incidence of 2.2%. This inherently stable transverse fracture (Fig. 2A) would have been better treated by the use of closed methods or by the application of closed intramedullary rod fixation.

The duration of the treatment period prior to the labeling of a delayed or nonunion is somewhat arbitrary. While Nicole defined it as 20 weeks, Burney assessed a nonunion on the basis of the time anticipated for union to occur for a particular fracture pattern allowing more prolonged healing time periods for more complex injuries. This concept seems to be particularly useful when partially or completely devitalized bone fragments of substantial size are present. Denuded fragments clearly require a much longer period of time for incorporation into the residual bone. \(^{24-26}\) Incidentally, in the presence of an open fracture, they predispose the wound to a much greater likelihood of a wound infection and, therefore, nonunion.

The AO ASIF group believes that the incidence of nonunion is reduced by the application of rigid fixation (Jensen—0%). \(^{13}\) Those in favor of functional weight bearing feel that this also results in fewer nonunions (Sarmiento\(^{+}\)). Most of the latter observations pertain to the treatment of closed or Grade I open tibial fractures, so that marked comminution and adjacent soft tissue disruption is generally excluded. Certain studies such as ours pertain to the management of a substantial number of unstable, comminuted or high velocity injuries where a higher nonunion rate would be anticipated irrespective of the method of treatment. Nonunion rates in similar series
are: Jensen—8.6%, Karlstrom—4.4%, Edwards—6.1%, Burwell—4.4%14. In our series four nonunions were encountered; three were related to infection and/or severe high velocity injuries. The fourth case (Fig. 3) represents improper application of a plate with distraction of the osseous fragments. Intraoperative radiographs would obviate such an occurrence. In addition, the reduction of the fracture fragments using lag screw fixation restores the continuity of the bone and greatly accelerates the anticipated rate of fracture repair.

After closed methods of treatment are employed, incidences of malunion between 5.7% and 10% have been documented.14,24 In most civilian and community orthopedic practices, such a high incidence is unacceptable. Malunion also may be secondary to implant failure. In previous studies, implant failure is reported to occur in 1% to 6% of the cases.12,21,24 It appears to be related to a combination of cyclic bending or fatigue forces applied to a plate which stabilizes a fracture where there is a residual osseous defect or other mode of instability. In our study, the patients were either nonweight bearing or at most undertook progressive weight bearing beginning with 25 pounds of force. In many cases, the breakage of a plate permits approximation of the fracture fragments possibly with angulation (Fig. 4). Our rate of implant failure (3%) is comparable to those rates reported previously. Internal fixation in the presence of structural osseous defects should be accompanied by the application of autologous cancellous bone graft to fill the defect.

Shortening appears to be related to the degree of weight bearing (Sarmiento—100%, Dehene—63%, Witschi—25%) as well as to the amount of bone loss. The application of plate fixation and anatomic reduction appears to result in markedly less shortening and residual deformity (Burwell—3.3%, Onnenfalt—15%, Karlstrom—2%).

Immobilization may result in joint stiffness, especially if it is undertaken for a prolonged period. The rates of stiffness following the use of closed methods of treatment are 25% to 50%14 versus 5% to 6% when methods of open treatment are employed.12,14,21,27 Our experience is between these two extremes. Our rate of 13.3% is easily appreciated when consideration of the individual fractures is taken into account. Three of six cases were infected or ununited, which required subsequent surgical procedures and immobilization. It is difficult to implicate the cast immobilization of three weeks in the other three fractures, since many similar fractures immobilized for periods of up to six weeks had no demonstrable stiffness. Our present belief is that once secure fixation has been obtained, immediate active motion of the adjacent joints should be encouraged.

Finally, in the previously published reports refractures are distinctly more common in cases that were treated by internal fixation (3% to 5%)12,24 than in those patients who were treated by the use of closed methods (1.4% to 3%).1 This observation may represent some patient selection by virtue of the therapeutic method chosen. Stress concentration through fibrous defects in cortical bone had generally been implicated.28,29 Some observers believe that curettage or overdripping of screw holes should be performed at the time of plate removal to encourage osseous ingrowth. Others feel that residual cortical defects can be discovered by the use of tomograms, and bone grafted at the time of plate removal.21 The authors recommend a delay in the removal of a plate for at least one year after its application despite the premature appearance of radiographic union.

Conclusions

For the treatment of the enormous spectrum of open and closed tibial shaft fractures with varied degrees of soft tissue and osseous injury, the therapeutic method requires careful selection if the optimal result with the least incidence of complications is to be realized. None of the available methods of therapy possess overwhelming advantages so that they can be routinely applied to all tibial shaft fractures. Each method possesses marked limitations which render it unsatisfactory for certain tibial fractures. Unstable fractures, either closed or those associated with minor soft tissue disruption may require the application of internal fixation. The exceptions would be those closed fractures with massive comminution or open fractures with high infective potential, which are best managed by the use of external fixation.

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References