Inter-tibiofibular graft for traumatic segmental bone defect of the tibia

F. Fitoussi a,∗, A.-C. Masquelet b, S. Rigal c, A. Poichotte d, T. Bauer e, A. Fabre f, the French Society of Orthopedic and Traumatologic Surgery (SoFCOT) 56, rue Boissonade, 75014 Paris, France

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KEYWORDS
Segmental bone defect; Bone reconstruction; Bone graft; Inter-tibiofibular graft; Bone healing

Summary
Introduction: The present study sought to assess the interest of inter-tibiofibular graft (ITFG), alternatively called posterolateral bone graft, in traumatic segmental tibial bone defect.

Material and methods: Twenty-eight ITFGs were performed in 125 tibial reconstructions for traumatic bone defect. Patient’s records were reviewed retrospectively in a multicenter study. Tibial reconstruction with and without ITFG was compared for bone healing and patient’s return to full weight-bearing status.

Results: There were no failures of bone healing in the ITFG group, versus 14 (14%) in the non-ITFG group. Graft-to-consolidation delays were shorter with first-line ITFG, at a mean 10 months (range, 3—20 months) versus 16.5 months (range, 3—63 months) in the non-ITFG group (P < 0.05). Weight-bearing was likewise more quickly resumed, with full weight-bearing at a mean 9 months (range, 3—19 months) versus 15 months (range, 1—34 months) respectively (P < 0.05). Return to work was also quicker, at a mean 15 months (range, 4—28 months) versus 27 months (range, 8—56 months) respectively (P < 0.05).

Discussion: This study confirmed the interest of ITFG in tibial bone defect reconstruction. ITFG may singly be used for small defects less than 4 cm, or in conjunction with another tibial reconstruction technique; ITFG in the present series achieved consolidation in all cases and significantly shortened the times to return to full weight-bearing status and to work.

Level of evidence: III: retrospective case-control study.
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Introduction

Treatment of traumatic tibial bone defect requires a comprehensive strategy including not only defect characteristics but also soft tissue status and the presence of active infection. Many tibial reconstruction techniques have been described: conventional graft, vascularized transfer, corticotomy with bone mobilization or two-step induced membrane reconstruction [1–7].

In contrast to this “focal” strategy, alternative strategies can achieve consolidation without necessarily reconstructing the tibia, relying on the fibula. Several variants using the fibula have been described, on short series [8–11].

The present study, under the French Society of Orthopedic and Traumatologic Surgery (SoFCOT) symposium on traumatic tibial shaft defect, sought to assess the interest of inter-tibiofibular graft (ITFG) in strategies to consolidate the tibial segment.

Material and methods

One hundred and twenty-five tibial reconstructions for traumatic bone defect were reviewed retrospectively in a multicenter study. Defects were either primary at trauma or secondary to surgical excision, usually for sepsis.

The reconstruction procedure, with or without associated ITFG, was conventional bone graft, reaming-irrigating-aspiration (RIA) graft, Papineau cancellous graft, bone mobilization, induced membrane or vascularized transfer.

Series

ITFG was performed in 28 of the 125 tibial reconstructions (22%), in third place after induced membrane and vascularized transfer as technique. The present analysis concerns these 28 patients.

First-line treatment

The mean age of the 28 ITFG patients was 30.2 years (range, 9–72 yrs). Trauma was mainly road accident (86%), most frequently involving a two-wheel vehicle. There were associated lesions in 43% of cases (visceral, cranial and most frequently orthopedic). There was right-side involvement in 15 cases.

Bone defect was primary in 14 cases (50%). Initial treatment was by spacer in four cases, shortening with or without bone contact in three and immediate bone reconstruction in one.

Three patients showed ischemia (11%) requiring revascularization and five showed neurologic lesions (18%).


opening was Cauchoux grade 2 in six cases, grade 3a in 9 and grade 3b in 13.

Primary osteosynthesis involved nailing in seven cases, external fixation in 17, plate in two and associated plate + external fixator in two.

Soft tissue reconstruction required a flap in 13 cases: two emergency, and 11 delayed between 3 weeks and 2.5 months.

A mean eight operations were needed before performing bone reconstruction (range, 0 to 25, including dressing under general anesthesia), and the mean interval between trauma and defect reconstruction was 190 days (range, 0 to 1460 days). The large number of operations and long intervals to reconstruction were due to infection, found in 21 cases (75%).

Pre-operative defect assessment found a diaphyseal location in 22 cases and a diaphyseal-metaphyseal location in 6. Mean defect size was 7 cm (range, 1.8–24 cm), distributed as follows: type 1, n = 5; type 2B, n = 1; type 2S, n = 9; type 3B, n = 1; type 3S, n = 6; and type 4, n = 6. On the Catagni classification, 20 patients were B1, one B2 and seven B3. Soft tissue quality was judged good in only four cases. Vascular exploration was conducted in 20 cases and found two permeable axes in three cases, one in three cases and no axis with collateral circulation in one. All other examinations were normal. Ankle motion was limited in half the cases and knee motion in one-fifth.

Assessment

Consolidation data were compared between two groups of patients who achieved union: tibial reconstruction without ITFG (n = 83) and reconstructions with first-line ITFG as part of the consolidation strategy (n = 20). The two groups were comparable for age and defect size (Table 1). Data for the two groups were compared by Student t test.

Results

Defect management

A mean 3.3 operations (range, 1–10) were required to achieve consolidation. Osteosynthesis was generally modified (23/28). Soft tissue distribution required a covering flap in 21 cases (9 free flaps, 12 pediculated fasciocutaneous or muscular).

ITFG was performed in two distinct situations:

• in first line in 20 cases, including seven as isolated treatment (Fig. 1) in type 1 or two defects of a mean size less than 4 cm (range, 2–10 cm). In the other 13 cases, ITFG was associated to tibial reconstruction by induced membrane or bone transfer as part of consolidation strategy (Fig. 2);

• in second line in eight cases of delayed consolidation at one extremity of the reconstruction.
Consolidation, resumption of weight-bearing and return to work

Results are presented in Table 1, comparing tibial reconstruction with first-line ITFG (n = 20) and reconstructions without ITFG (n = 83).

There was no failure of consolidation in the ITFG group, versus 14 cases, usually leading to amputation, in the non-ITFG group.

In case of consolidation, the interval after grafting was shorter in the ITFG group, at a mean 10 months (range, 3–20 months) versus 16.5 months (range, 3–63 months) in the non-ITFG group (P < 0.05).

Weight-bearing was also resumed more quickly, in the ITFG group, at a mean 9 months (range, 3–19 months) versus 15 months (range, 1–34 months) in the non-ITFG group (P < 0.05).

Return to work was likewise earlier, at a mean 15 months (range, 4–28 months) versus 27 months (range, 8–56 months) in the non-ITFG group (P < 0.05).

In all, first-line ITFG, whether isolated or in association, as an integral part of tibial consolidation strategy

<table>
<thead>
<tr>
<th></th>
<th>ITFG</th>
<th>non-ITFG</th>
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<tbody>
<tr>
<td>Number</td>
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</tr>
<tr>
<td>Age at trauma</td>
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<tr>
<td>Mean defect size</td>
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<td>8.5</td>
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<td>Time to return to work from reconstruction (months)</td>
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<td>0.0074</td>
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</table>

ITFG: inter-tibiofibular graft.

**Table 1** Comparison between tibial reconstruction with first-line inter-tibiofibular graft as part of the consolidation strategy and without inter-tibiofibular graft (in both groups, all patients achieved consolidation).

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![Figure 1](image-url) A. Tibial fracture with bone defect and intermediate fragment managed solid inter-tibiofibular graft. B. Postoperative aspect. C. Consolidation.
significant improved consolidation time, resumption of weight bearing and return to work.

When ITFG was performed secondarily, consolidation was systematically achieved, at a mean interval of less than 6 months.

Discussion

Despite recent advances in reconstruction surgery, notably the modern concepts of vascularized bone transfer, bone mobilization and induced membrane, management of traumatic tibial bone defect remains difficult. To ensure consolidation, the surgeon needs to take account not only of the size and characteristics of the defect itself but also of possible active infection and of the soft tissue lesions that are systematically associated. Treatment comprises preliminary treatment of the sepsis, the recommendations now being to take no chances with infection, a possible soft tissue repair step and finally the tibial reconstruction step. These three steps can be separate or associated.

In view of the difficulties involved in this focal strategy, many authors have recommended an inverse attitude, focusing on the fibula in managing such complex non-union [12–21]. In 1939, Milch [12] was the first to describe tibiofibular synostosis for tibial non-union. In 1945, Harmon [13] described a posterolateral approach remote from the cutaneous lesions; and in 1955, Jones [14] presented the first series of ITFG in tibial non-union. These precursors set out the three fundamentals of this technique:

- consolidation can be achieved despite active anteromedial infection, with the interosseous membrane theoretically acting as barrier;
- the lateral side of the leg is usually spared by the initial trauma, making surgical approach and graft integration possible;
- tibial reconstruction is not a prerequisite for consolidation. These three points allow a strategy based on avoiding the infectious, cutaneous and osseous problems.

The present study confirmed the interest of ITFG in the consolidation step of tibial bone defect treatment. Three situations may be distinguished:

- isolated ITFG, usually for defects smaller than 4 cm, especially when the reconstruction space has not been conserved. Tibial reconstruction is not a prerequisite for achieving bone continuity. The fibula consolidates solidly with the bone graft to form a tubular neo-os that is strong enough to support unipodal weight-bearing during gait (Fig. 1).
- associated ITFG, in a regional strategy for tibial consolidation. ITFG may, for example, be unipolar, concluding bone transfer, or bipolar in induced-membrane tibial reconstruction, to lock the extremities of the reconstruction (Fig. 2). In the present series, consolidation with such associations was systematic, with significantly shortened times to resumption of weight-bearing and return to work.
- salvage ITFG, in case of delayed consolidation at one extremity of the reconstruction, using whatever technique. Here again, in the present series, consolidation was systematic in these situations.

The interest of ITFG in tibial bone defect was previously reported in several smaller series. Rinjberg and Ryzewicz [10,11] treated respectively 17 and 18 defects ranging from 1 to 20 cm by isolated anterior or posterior ITFG. The consolidation rate in both series was 95%, but time to consolidation cannot be specified as the authors grouped non-union with and without bone defect together. Vidal [22] used first-line ITFG in 9 patients with 3 cm traumatic superior tibial defect; consolidation was systematic, at a mean 10 months, in line with the present findings.

Technique is fundamental in performing ITFG. Vidal [22], in a series of 47 ITFG, reported a failure rate of one-third, due to defective technique: inadequate non-union site bridging, insufficient bone graft, or fibular non-continuity.

To ensure success, a number of technical criteria have to be met:

- the approach should be determined according to arthrography and the soft tissue lesions, and will usually be posterolateral in ventral decubitus. An anterolateral approach [11], forward of the fibula between the extensor digitorum and fibularis muscles, may be preferred, notably when the peroneal artery is to be conserved in case of single axis; in this case, patient positioning is in lateral or three-quarter decubitus and fibial and fibular osseous membrane release should enable graft positioning;
• the fibula must be continuous, but not necessarily consolidated. It may be stabilized by an intramedullary pin or a screwed plate;
• the bone graft must be solid: it may be an impacted bicortical monoblock, with possible pin stabilization. A tibial trench can enhance stability, with impaction to improve graft integration. The bone graft may also be cancellous, placed on the membrane, or a combination of the two;
• it is essential to decorticate the tibia and fibula with an osteotome and bone nibblers in the areas in contact with the graft;
• the graft should bridge the defect by at least 4 cm on either side;
• assembly stabilization is another key-point: an external fixator should be used instead of the classic plaster. Bipolar tibiofibular screwing can strengthen the framework.

Tibiofibular synostosis has been reported to impair ankle motion, but this could not be clearly demonstrated from the present series, due to the severity of initial trauma, soft tissue lesions, multiple operations and prolonged immobilization.

Other applications of the ipsilateral fibula have been described in this context. Medialization of a fibular segment and bipolar fusion with the tibia was first described by Huntington in 1905 [8]. Since this princeps report, other "fibular tibialization" techniques have been described:

• extemporaneous transfer of a muscular pediculated segment or a true peroneal artery vascularized graft [9,23–26];
• or more progressively, usually with an Ilizarov fixator [2,27].

Fibular tibialization, depending on the author, is basically indicated for large bone defects and often for limb salvage after repeated attempts, particularly when the medial side of the leg is severely scarred.

In the present series, eight patients were managed by fibular tibialization. Their presenting lesions were generally more severe than in the series as a whole, with larger defects not filled by initial debridement and fixation. Soft tissue assessment usually found poor quality coverage or skin loss, making the medial part of the leg unserviceable. A large majority of the patients had infection. Consolidation was nevertheless systematic (Fig. 3), at a mean 12.8 months after tibialization (range, 4–23 months), somewhat faster than in the series as a whole (mean, 16.5 months) although not significantly so (P > 0.05).

Many other applications of the fibula in case of bone defect have been described: combplates, non-vascularized fibula impacted in a membrane, spacer applied to the fibula to create an ITFG mirror effect, etc. In primary treatment of complex leg fracture, the surgeon needs to bear in mind the various possibilities for subsequent reconstruction relying on the fibula, performing a precautionary alignment osteosynthesis during initial trauma treatment, for example, or applying a spacer to the fibula when the reconstruction space is filled.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.
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