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# Treatment of tibial shaft bone loss by segmental bone transport in a country with limited resources about 6 cases

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## Abstract
**Introduction:** Loss of bone substance (LBS) in the limbs is serious and difficult to treat. Especially in our countries, which are characterized by a lack of technical, infrastructural and, above all, financial resources. The aim of this study is to describe our experience of reconstruction using an adapted external fixation and to evaluate our anatomical and functional results.
**Patients and Methods:** This was a retrospective, single-centre study of 6 patients managed between 2017 and 2022 in Douala, Cameroon. The mean age was 30, 5 years, there were 4 males and 2 females. The initial injury was an open fracture. In 1 case the PSO was caused by the trauma and in 5 cases by resection of osteitis. The mean size of the OSF was 9 cm, 5 times diaphyseal and 1 time distal diaphysometaphysal. According to Masquelet's classification, there were 3 cases of type 4 and 3 cases of type 3. Bone transfer was indicated after unsuccessful reconstruction using the Masquelet method in 1 case, the Papineau method in 1 case, and immediately after excision of osteitis in 4 cases. 1 medial gastrocnemius flap, 1 medial soleus flap with a distal pedicle, 1 posterior fasciocutaneous flap with a distal pedicle, and 1 posterior fasciocutaneous flap with a distal pedicle were used. In 5 of the 6 patients, 1 staphylococcus aureus was isolated 3 times, 1 Escherichia. Coli 1 time and 1 pseudomonas auruginosa 1 time. Surgery was performed on a standard table without image amplification. It involved a hybrid monoplane external fixture consisting of two fixators arranged as follows: a dynamic implant combined with a Hoffmann I fixator for patients 1 and 3 and a standard AO fixator for patient 2. Patient 4 had an external fixator consisting of 3 semi-circular rings. Patients 5 and 6 benefited from a rail-mounted monoplane external fixator. Radiographic and functional results were analysed using the Paley and Maar radiographic and functional scores.
**Results:** Our follow-up was 46.5 months, the mean duration of transport was 3.96 months, and the mean size of the segment transported was 16.58 cm. The mean time to weight-bearing was 14.6 months. There were no regenerate fractures. The Paley and Maar functional score was excellent 3 times, good 2 times and poor 1 time. Monopodal weight-bearing was possible and pain-free. The Paley and Maar bone score was excellent 3 times, good 1 time and poor 1 time.
**Conclusion:** Reconstruction using segmental bone transport is a reliable, reproducible, and adaptable method. It gives satisfactory results in our context.

**Keywords:** Bone loss, segmental bone transport, Douala Cameroun

## Introduction
Bone loss (B.L.) of the limbs is a serious lesion that is difficult to treat [1, 2]. Especially in our countries characterized by lack of resources. All things leading in many cases to amputation. Several therapeutic methods have been developed for the treatment of PSO of the limbs: bone autografts, vascularized bone grafts [3, 4], the induced membrane technique [5, 6] or bone mobilization methods such as segmental bone transport (S.B.T.) [7, 8] based on distraction osteogenesis initially described by Ilizarov and Ledyaev and conceptualized by Cattaneo [9, 10] who used a circular and subsequently monorail external fixator. Bone mobilization techniques have produced good results in the literature, especially in large B.L. They involve experiential know-how; are irreplaceable in certain situations, notably S.B.T. which is the only process allowing both reconstitution of the bone defect and restoration of the length of the limb segment [11-16]. Bone mobilization techniques do not always require prior repair of the soft tissues.

In particular, it is necessary to ensure that the bony ends are sufficiently covered so as not to risk their exteriorization during the migration of the segment [1, 17]. What about our attitude towards these lesions? Through a retrospective study, the authors wanted to describe their experience of tibial diaphyseal reconstruction using segmental bone transport using suitable external fixation and evaluate their anatomical and functional results.

**Patients and methods:** This was a retrospective, single-center study of 6 patients treated in 2017 and 2022 at the Laquintinie hospital in Douala, Cameroon. The average age was 30.5 years (17-41). There were 4 men and 2 women. The initial injury was a fracture following a road accident (R.A.). All these initial fractures were open; 3 were type 2 of Gustillo Anderson (GA), 2 of type 3b of G.A. and 1 type 3a of G.A. The B.L. was immediately present during the trauma only once and 5 times it was due to resection of osteitis. The average size of the B.L. was 9 cm (4-12). It was diaphyseal 5 times (4 times 1/3 distal and 1 time in the middle 1/3) and 1 time diaphysometaphyseal distal.
The average time between the initial trauma and the start of bone transport was 7.66 months (1.5-18). According to the Masquelet classification, there were 2 cases of type 4 and 4 cases of type 3. Bone transport was indicated after failure of reconstruction using the Masquelet method once in patient 1 (P1), by that of Papineau once in Patient 2 (P2) and immediately after excision of osteitis 4 times (P3, P4, P5, P6). Several shreds of covers were made. In patient 1, a medial gastrocnemius flap and a medial hemi-soleus with a distal pedicle, then a fascio cutaneous flap with a distal pedicle after the latter failed (figure 1) and in patient 3, a medial translation fascio cutaneous flap. Two thin skin grafts were performed in patients 1 and 2.

**Fig 1**: Medial gastrocnemius flap, medial hemisoleus with distal pedicle (a) and sural with distal pedicle (b, c) in P1

Most patients had been operated on several times before transport P1 (4), P2 (1), P3 (2), P4 (2), P5 (1), P6 (2), an average of 2 (1-4), in 5 of the 6 patients a germ had been isolated at the start of transport. It was a staphylococcus aureus 3 times, an *Escherichia coli* 1 time and 1 pseudomonas auruginosa 1 time. Only patient 2 was aseptic. These infections required antibiotic therapy adapted to the antibiogram for an average of 2 months. The surgical procedure was carried out by the same operator always on an ordinary table without image amplification. The first stage consisted of samples for cytobacteriological examination and antibiogram, then debridement with resection of the osteitis when it existed down to the macroscopically healthy tissue using rongeurs and striking chisels, then careful cleaning of the space. Reconstruction. The second stage corresponded to the placement of the external fixator (E.F.): For patients 1, 2, and 3; this is a hybrid monoplane external assembly consisting of two fixators and arranged as follows: a Hoffmann I fixator for patients 1 and 3 and a standard AO fixator for patient 2, the Proximal pins of which were positioned at the metaphysis or at the proximal 1/3 of the diaphysis; the distal pins were positioned at the distal metaphysis. The role of this fixator was to maintain the length of the limb throughout the procedure. This length was determined in relation to the healthy limb. A second dynamic monoplane Wagner type fixator from the Stryker company arranged in such a way that its proximal pins placed in the middle third of the tibial diaphysis were independent of the first fixator, while its distal jaw was linked to the distal pins of the latter. (Figure 2)

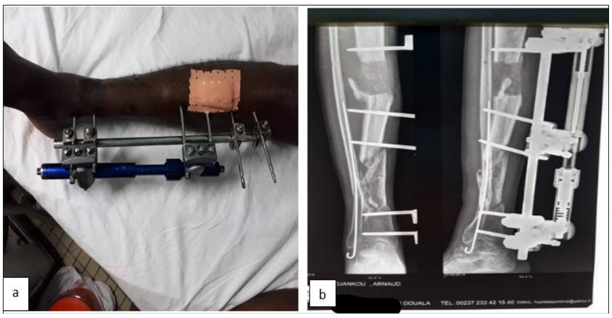

**Fig 2:** hybrid assembly with a universal AO fixator and a dynamic fixator (a), radiographic control (b)

Patient 4 had benefited from an external fixator composed of 3 semi-circular rings, and arranged as follows: The first 2 were placed in front of the leg and connected by two dynamic rods, the third more distal, behind the ankle and connected to the first with 2 rigid rods to maintain the length of the leg; this ring was independent of the second. A flag above the first ring made it possible to place screws in the proximal third of the tibial diaphysis and extensions placed above the middle ring made it possible to place screws in the middle third of the diaphysis. Pins were positioned in the tibial pilon through the distal ring under which extensions allowed placement of pins in the talus and calcaneus (Figure 3)

**Fig 3:** Assembly with Orthofix® semi-circular fixator (a), radiographic control (b).

Patients 5 and 6 benefited from a single-plane external fixator on a rail, allowing pins to be placed in the proximal third, the middle third of the diaphysis and the distal metaphysis. This implant has a dynamic device between 2 jaws that can provide distraction. (Figure 4).

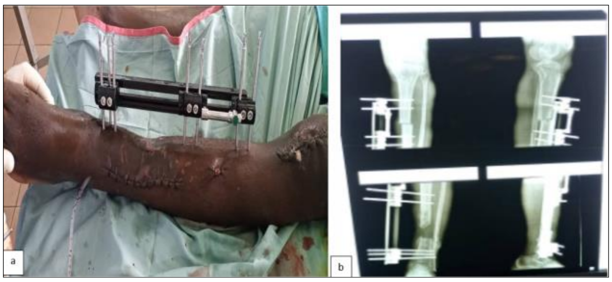

**Fig 4:** Assembly with one-piece fixator on sofemed® brand rail (a), radiographic control (b).

The third step consisted of performing a postage stamp osteotomy, first with drill bit 3.2, then with chisels to strike equidistant between the proximal and middle pins through a mini approach. The direction of mobilization was always downward and made it possible to obtain osteogenicity in the distraction space, while the PSO was filled.

Distraction had always started on the 10th postoperative day. It was carried out for a few days in hospital and continued on an outpatient basis. After filling the B.L., the external devices were locked for 5 months necessary for the consolidation of the regenerate. After this period, a pseudarthrosis treatment at the filling area was carried out with decortication and iliac osteochondral grafting and osteosynthesis using an external fixator of the FESA type for patient 1, standard AO for patients 2, 3 and 4 and a screwed plate. For P5 and P6. Local care around the files was done with 90° alcohol morning and evening. Clinical and radiographic follow-up was carried out every 6 weeks. Resumption of weight bearing was authorized upon consolidation of the pseudarthrosis site. For each patient, we determined the criteria set out by Fischgrund *et al.* [10] including: the external fixation index (EFI) = duration of wearing the EF in months divided by the length of the PSO and the radiological consolidation index (RCI) = duration of bone consolidation in months divided by the length of the PSO in cm. The radiographic and functional results were analyzed using the radiographic score and the Paley and Maar functional score [11] (Table 1 and 2).

**Table 1:** Paley and Maar Functional Score

| | |
|---|---|
| Excellent | Patient pain-free, walking without assistance, without fixed joint stiffness above and/or underlying, without loss of talocrural or subtalar mobility greater than 20° and independent for the majority of his daily activities without difficulty |
| Good | Pain-free patient, independent for the majority of his daily activities without minor difficulties, with one of the following criteria: walking aid, fixed joint stiffness above and/or underlying, loss of talocrural or subtalar mobility greater than 20 |
| Average | Patient painless or not very painful, independent for the majority of their daily activities with minor difficulties, with the following two criteria: walking aid, fixed joint stiffness above and/or underlying, loss of talocrural or subtalar mobility greater than 20° |
| Poor | Any patient requiring analgesics or having a limitation in daily activities or presenting all of the following criteria: walking aid, fixed joint stiffness above and/or underlying, loss of talocrural or subtalar mobility greater than 20° |

**Table 2:** Paley et Maar Anatomical Bone Score

| | |
|---|---|
| Excellent | Consolidation, absence of infection, absence of axis defect greater than 5°, inequality in limb length less than 2.5 cm, consolidation of the receptor site and the osteogenesis zone strong enough to do without protection |
| Good | Consolidation without infection with one of the following criteria: axis defect greater than 5°, length inequality greater than 2.5cm |
| Average | Consolidation without infection with the following two criteria: axis defect greater than 5°, length inequality greater than 2.5cm or patient presenting insufficient consolidation of the receptor site or osteogenesis zone |
| Poor | Pseudarthrosis and/or bone infection |

**Results**

Our follow-up was 46.5 months (28-72), the average duration of transport fixation port was 8.99 months (7.66-11), the average size of the transported segment was 16.58 cm (12 -22). The average size of the regenerate was 9.6 cm (6-14). The average duration of transport was 3.96 months (2.6-6), the average time between the start of transport and support was 14.66 months (10.66-18.5). All patients had returned to their previous activity. Patient 4 is still in pseudarthrosis and wanted to continue her treatment with bonesetters. The average EFI was 1.06 months/cm (0.83-1.53) and the average RCI was 1.6 months/cm (1.16-2.13) the average time to union of the site recipient was 4.6 months (3-6).

In our series, only one patient had an aseptic filling area at the start of transport. All our patients developed an infection around the pins which persisted in patients 4 and 3 until the oblation of the external transport fixator despite local care and antibiotic prophylaxis. The distraction device seized twice in patient 4, and once in patients 3, 5, 6 requiring them to be unblocked and repositioned. We did not have any fractures of the regenerates. At the end of the transport, we noted an axial valgus deformation of the regenerate 4 times (P1: 30°, P2: 18, P3: 12°, P4: 35°) (Figure 5), and a shortening of the limb by

2.5 cm once. The functional score was excellent in 3 patients (P2, P5, P6), in the patient who was aseptic at the start of transport and in those who benefited from an external fixator on a rail. It was good twice (P1 and P3) due to residual ankle stiffness and bad once in the patient with pseudarthrosis. In other patients, monopodal support is possible and without pain.

The Paley and Maar bone score was excellent twice (P5, P6), good once P1 due to a valgus of 30°, average once due to a valgus of 12° due to an inequality in length > 2.5 cm at P3. In addition, it was poor once in patient P4 with pseudarthrosis.


**Fig 5:** Valgus deviation of 30° in $P_{1.}$

**Table 3:** Main patients characteristics

| Patients | Age at start of transport | Sex | Type of skin opening (Gustillo) | Etiology of bone loss | Topography of bone loss | Classification of bone loss (Masquelet) | Number of surgeries before transport | External fixation type | Cover gesture (Flap) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 17 | F | IIIb | Ostéitis | Distal third | 4 | 4 | Hoffman 1 fixator type + Dynamic fixator | -Medial gastrocnemius flap<br>-Hemisoleal flap with distal pedicle<br>-Sural flap with distal pedicle |
| 2 | 31 | M | II | Immediately during the trauma | Distal third | 3 | 1 | AO fixer + dynamique fixator | -Fasciocutaneous medial translation flap |
| 3 | 41 | M | IIIa | Osteitis | Distal third | 4 | 2 | Hoffman 1 fixer type + dynamic fixator | |
| 4 | 27 | F | II | Osteitis | Diaphyso metaphyseal distal | 3 | 2 | Circular fixator | |
| 5 | 39 | M | II | Osteitis | Middle third | 4 | 1 | Rail-mounted External fixator | |
| 6 | 28 | M | II | osteitis | Distal third | 3 | 2 | Rail-mounted external fixator | |

**Table 4:** Main Résults

| Patients | Loss of bone Substance (cm) | Size of bone transported segment (cm) | Duration of Transport (Mois) | Duration of Wearing external fixator (Mois) | Radiological consolidation Index (Mois/cm) | External fixation index (Mois/cm) | Time for consolidation of the filling site (Month) | Follow-up (Month) | Anatomical results (Peley and Maar) | Functional Results (Paley and Maar) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 18 | 6 | 15 | 1,2 | 0,9 | 4 | 72 | Good | Good |
| 2 | 7 | 14 | 2,8 | 13,7 | 1,9 | 1,1 | 6 | 53 | Excellent | Excellent |
| 3 | 12 | 10 | 5 | 14 | 1,1 | 0,8 | 4 | 48 | Good | Average |
| 4 | 8 | 22 | 3,3 | 8 | - | 1,0 | - | 40 | Poor | Poor |
| 5 | 10 | 12 | 4,1 | 15,1 | 1,5 | 0,9 | 6 | 38 | Excellent | Excellent |
| 6 | 5 | 19 | 2,6 | 10,6 | 2,1 | 1,5 | 3 | 28 | Excellent | Excellent |
| Average | 9 | 15,8 | 3,9 | 13,6 | 1,6 | 1,0 | 4,6 | 46,5 | - | - |

## Discussion

We had previously performed several covering flaps, particularly in patients P1 and P3, before the procedure in accordance with the recommendations of Masquelet *et al.* and Rigal *et al*. In order to ensure that the bony ends are sufficiently covered so as not to risk their exteriorization during the migration of the segment [1, 17]. Ferchaud *et al.* [18] recalled that the segmental bone transport technique takes into account two distinct phases: that of osteogenesis in the distraction site and that of consolidation of the filling site. The EFI reflected the osteogenesis phase and the duration of this phase varied depending on the techniques. It was 1 to 1.9 months/cm in those using the Ilizarov technique [11, 19, 20]. In those using an external fixator guided by intramedullary nailing, removal of the external fixator was early at the end of distraction and the EFI varied between 0.45 and 0.87 months/cm. Our EFI was 1.06 months/cm (0.83 to 1.52), within the average of those using ilizarov-type fixation and higher than that of studies where transport was guided by a nail. Five months after the end of transport, there was still a non-union at the filling site and all patients had benefited from decortication, an iliac osteochondral autograft and osteosynthesis using an external fixator 3 times and per Plate marked twice. In the literature, the reconstruction site benefited from the addition of graft on a case-by-case basis [11, 22, 23, 24], sometimes systematically as in our series [22, 25, 26] or was not the subject of no additional gesture for certain authors [8, 27]. The RCI reflected the consolidation phase of the filling site. In our study, its average was 1.6 months/cm and it ranged from 1.1 to 2.1 months/cm. These results were similar to other series with recipient site graft where the RCI varied from 1.1 to 2.1 months/cm, and in that without graft where the RCI varied from 1.3 to 2.4 months/cm. According to the above, the exofixations adapted from our practice presented similar results in terms of time to union and duration of external fixation as those of transport studies using only the external fixator. However, compared to the series of transport by external fixation guided by a nail, our results were comparable in terms of time to union, but the duration of external fixation was logically longer. Several complications were recorded in our series. Regarding infections, most authors mentioned them around the forms and in the filling space with a rate that varied between 5 and 100% [1, 2, 19, 24]. However, they had not been a hindrance to the procedure because this technique had given satisfactory results without necessarily drying them out. Unlike Trigui *et al*. [19], who in their study found no infection of the nonunion area, only one of our patients presented asepsis of this filling area. All of them had developed an infection around the plugs at least once during transport. Debridement and radical surgical excision of infected tissues were the prerequisite for reconstruction. The reasonable attitude would consist of planning two operating times; after radical excision, a cement spacer would maintain the reconstruction space, play the role of sentinel, and induce a foreign body membrane which itself would have an inducing nature on bone consolidation. The reconstruction will be carried out secondarily according to the process with which the team has experience inside the biological chamber formed by the membrane [1, 17]. We combined debridement plus excision of infected tissues with appropriate antibiotic therapy and local care around the files. Axis control remains a major problem in bone reconstructions. In series using an Illizarov external fixation., the axis defect rate varied between 16 and 44% [8, 19, 21, 28]. We observed a frontal axial deformation 4 times, always in valgus and centered at the distal end of the regenerate which could find an explanation in the precarious quality of our assembly which three times (P1, P2, P3) included two fixators. The dynamic implant had its proximal pins on the intermediate fragment. Due to its weight, it had a tendency to tilt during the procedure, bringing with it an inflection of the transported fragment, thus creating a valgus deformity. This deformation was also observed in patient P4 whose exofixation was carried out with a semi-circular device, because her medial distraction rod had seized and the patient unfortunately did not integrate all the instructions, the discovery was made. Made late at the end of the procedure. Since then we have opted for a S.B.T. using an external fixator on a one-piece rail whose stability ensures the maintenance of the axis of the mobilized fragment. For the success of the bone transfer, the assembly must combine the firmness of the fixation and the simplicity of dynamization. It is important to keep the bone ends well aligned and stable. The great instability of the material can lead to complications such as premature union, non-union or axial deviations [19]. Length inequalities greater than 3 cm were found in the series using the Illizarov FE [8, 11, 19, 29, 30]. In studies with nail-guided transport, lower limb length was determined by preoperative planning, reducing the risk of length inequality. No length inequality greater than 1 cm was reported [18, 22]. In our study only one patient had an inequality greater than 2.5 cm. This was due to early ossification observed in the filling space. All things having not allowed a confrontation of the transported intermediate and distal fragments. During the treatment of pseudarthrosis, compression of the site after decortication and grafting caused a loss of length of the diaphysis. The latter had nevertheless been compensated by a sole. Paley *et al*. had described a system for analyzing bone reconstructions based on bone and functional criteria [11]. Authors using the Illizarov external fixation report 65 to 79% excellent bone results and 0 to 63% excellent functional results. Paley *et al*. emphasized that functional results were not correlated with bone results. They explained the poorer functional results by the importance of the associated lesions. We found this difference in our series with 2 excellent bone results and 3 excellent functional results. Only patients who benefited from external fixation on a more suitable rail had excellent functional and bone results. In all patients, monopodal support is possible and without pain except in P4 with progression towards a pseudarthrosis (Figure 6)

**Fig 6:** Monopodal support in P2 and P3 (a, b). P4 pseudoarthrosis (c).

## Conclusion

The bone transport technique finds its place in the treatment of extended PSO of the leg and allowed the preservation of the limb in 6 cases with consolidation in 5 cases; But it requires a long procedure with heavy antibiotic therapy and very careful monitoring. It is a reliable method: infection is not a hindrance to the procedure, reproducible, adaptable: all you need is a dynamic fixative. the results in our context are satisfactory and several amputations were thus avoided.

**Conflict of Interest**
Not available

**Financial Support**
Not available

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