Distraction Osteogenesis Technique Using an Intramedullary Nail and an External Fixator in Large Bone Defects

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ABSTRACT

Introduction: The proper treatment of bone defects represents a challenge for the orthopedic surgeon given the difficulty in restoring limb alignment without discrepancy nor infections. Multiple techniques have been described for the reconstruction of these defects. These include bone grafting, whether autologous or from a bank, the induced membrane technique, distraction osteogenesis, and, recently, the use of trabecular titanium cylinders, but none has been shown to be significantly superior to another. **Materials and Methods:** Between 2018 and 2021, ten patients with tibial bone defects were treated by guided bone transport with intramedullary osteosynthesis. We carried out a descriptive retrospective study of this series, analyzing the magnitude of the defects, the transport time, the complications and additional surgeries that took place during the process, whether there was consolidation, and the residual deformities. The bone and functional ASAMI scores were measured at the end of the process. **Results:** The average length of the treated defects was 9.75 cm and the average external fixation index was 40.62 d/cm. At the end of the reconstructive process, 50% of the patients presented a good bone ASAMI score, 10% presented an excellent score, and 40% had a poor score. Regarding the functional ASAMI score, 20% were excellent, 30% were good, and 50% were poor. **Conclusion:** The use of fixators guided by intramedullary nails constitutes a reliable method to treat bone defects that allows treating the infection locally and systemically, shortens the times of external fixation and hospitalization, and reduces the need for reinterventions.

Keywords: Lengthening over a nail, Masquelet, bone defect
Level of Evidence: IV

Transporte sobre clavo respetando la membrana de Masquelet en defectos segmentarios severos. Serie de casos

RESUMEN

Introducción: El adecuado tratamiento de los defectos óseos se presenta como un desafío para el cirujano ortopedista, en cuanto a la dificultad en la restitución de un miembro alineado, sin discrepancia y sin infección. Se han descrito múltiples técnicas para reconstruir estos defectos, como el injerto óseo autólogo o de banco, la técnica de membrana inducida, la osteogénesis por distracción y los cilindros de titanio trabecular, pero ninguna ha demostrado ser significativamente superior a otra. **Materiales y Métodos:** Entre 2018 y 2021, 10 pacientes con defectos óseos de la tibia fueron tratados mediante transporte óseo guiado con osteosíntesis endomedular. Se realizó un estudio retrospectivo descriptivo analizando la magnitud de los defectos, el tiempo de transporte, las complicaciones y cirugías adicionales durante el proceso, si hubo consolidación y las deformidades residuales. Al final del proceso, se midió el puntaje de la ASAMI (óseo y funcional).**Resultados:** La longitud promedio de los defectos tratados fue de 9,75 cm y el índice de fijación externa promedio, de 40,62 días/cm. El 50% de los pacientes tenían un puntaje de la ASAMI óseo bueno; el 10%, excelente y el 40%, pobre al final del proceso reconstructivo. El 20% tenía un puntaje de la ASAMI funcional excelente; el 30%, bueno y el 50%, pobre. **Conclusiones:** El uso de tutores externos guiados mediante osteosíntesis es un método fiable para tratar defectos óseos, al mismo tiempo que se tratan la infección de manera local y sistémica, acortando los tiempos de tutor externo y, por lo tanto, de internación y reintervención.

Palabras clave: Alargamiento sobre clavo; Masquelet; defecto óseo.
Nivel de Evidencia: IV

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INTRODUCTION

The proper treatment of severe segmental bone defects represents a challenge for the orthopedic surgeon, given the difficulty in restoring limb alignment without discrepancy, infections, or associated vascular or nervous injuries.[1-3]

One of the pillars for effective treatment is a good debridement of the infection site and any devitalized tissue around it, in order to obtain a favorable biological environment for bone and soft tissue reconstruction.

Multiple techniques have been described for bone defect treatment, including bone grafting —whether autologous or from a bank—, the induced membrane technique, distraction osteogenesis, and, recently, the use of trabecular titanium cylinders.[4-6]

The distraction osteogenesis method described by Ilizarov in the 1950s has been proven to be effective to treat severe bone defects.[7,8]

Ilizarov outlined osteogenesis by distraction or generation of new bone tissue to consolidate the pseudoarthrosis, correct deformities, eradicate infections, reestablish the limb's length, or eliminate bone defects, allowing for weight-bearing with the appropriate device. One of the difficulties posed by this treatment is the patient's low tolerance to the external fixator, as it must remain installed for a long period.

At present, the reconstruction team's efforts aim at improving the patient's tolerance to the treatment, reducing the usage time of the fixator without compromising the mechanical environment needed to achieve an adequate result.

To solve this problem, we currently use "integrated" techniques, associating the internal fixation —called LON (Lengthening Over Nail) or LOP (Lengthening Over Plate)— with the aim of diminishing the most frequent complications, related to misalignment and external fixation times.[9]

The objective of this study was to describe the functional and radiographic results, as well as the complications throughout the reconstructive process for severe bone defects, treated with bone transport by external fixation with intramedullary osteosynthesis.

MATERIALS AND METHODS

A descriptive retrospective study was carried out in a referral center of traumatology, based on patients with segmental bone defects treated with LON transport, between January 2018 and January 2021. The study variables were retrospectively recorded from health records and images: magnitude of defects, transport time, complications according to the Paley classification[10], and results based on the ASAMI score (Association for the Study and Application of the Method of Ilizarov) (bone and functional).

The inclusion criteria were: adult patients with segmental bone defects >3 cm, infection-related pseudoarthrosis (Paley classification B and beyond) (Figure 1).

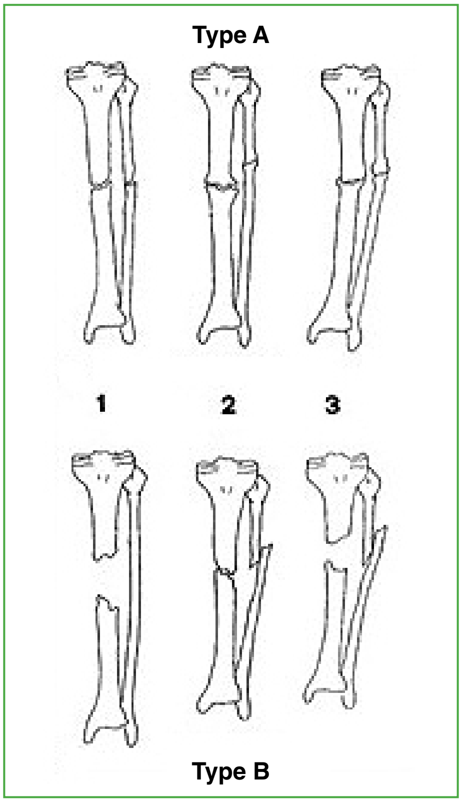

Figure 1. Paley classification of pseudarthrosis. Pseudoarthrosis type A (no consolidations with <1 cm of bone loss): AI (mobile); A2, rigid (non-mobile); A2-1, no deformity; A2-2, fixed deformity. Pseudoarthrosis type B (no consolidations with bone loss >1 cm): B1, bone defect, no shortening; B2, shortening, no bone defects; B3, bone defect and shortening.

The exclusion criteria were: vascular or nervous alteration, open physis and loss of follow-up (Table 1).

Table 1. Sample Description

Variable	
Cases	10
Age, median (range)	69 (27-72)
Sex, n (%)	
Female	3 (30%)
Male	7 (70%)
Diagnosis, n (%)	
Osteomyelitis	3 (30%)
Exposed fracture	7 (70%)

Treatment protocol

All procedures were performed under spinal anesthesia by the same surgical team. The protocol issued by our Limb Reconstruction Unit was followed in every case.

First stage

Massive debridement of devitalized tissue (Figure 2).

Figure 2. Intraoperative image. Debridement of devitalized tissue.

Bone stabilization with intramedullary nail covered by antibiotic-imbued cement. Soft tissue coverage. In every case, the third dead space generated by bone resections was handled using a circumferential spacer of antibiotic-imbued cement, fragmented into two hemicylinders to facilitate extraction (Figure 3).

Figure 3. Intraoperative image. Placing of the spacer divided into two parts.

Bone and soft tissue samples were taken in every case for microbiological and histopathological analysis In the cases of remnant infection, the intravenous treatment was performed jointly with the Infectious Diseases Service.

Second stage

The second stage is bone reconstruction (within 6-8 weeks of the first stage) by Masquelet's original technique.[11] The first action consists in extracting the cement spacer implanted with the same approach used in the first surgery, or raising the coverage flap. The peri-spacer membrane was always respected to preserve its osteogenic capability. The osteosynthesis was subsequently replaced by a short nail (8-9 mm) without cement cover and the canal was reamed again to obtain new samples. The external fixator's Schanz pins were inserted, using a unilateral tutor for eight patients (80%) and a circular tutor for the rest (20%). A metaphyseal corticotomy was performed in the longest remaining segment.

The last step consisted in placing the distraction system; a correct distraction of the corticotomy was verified (Figures 4 and 5).

Figure 4. Intraoperative image of the placing of the LRS type uniplanar external fixator.

Figure 5. Anteroposterior and lateral radiographs of the left leg, postoperative. See the defect, the corticotomy and the mounted system: external fixator, intramedullary nail.

All patients followed a distraction protocol of 1 mm/day, divided into four 0.25 mm distractions every 6 hours (Figure 6).

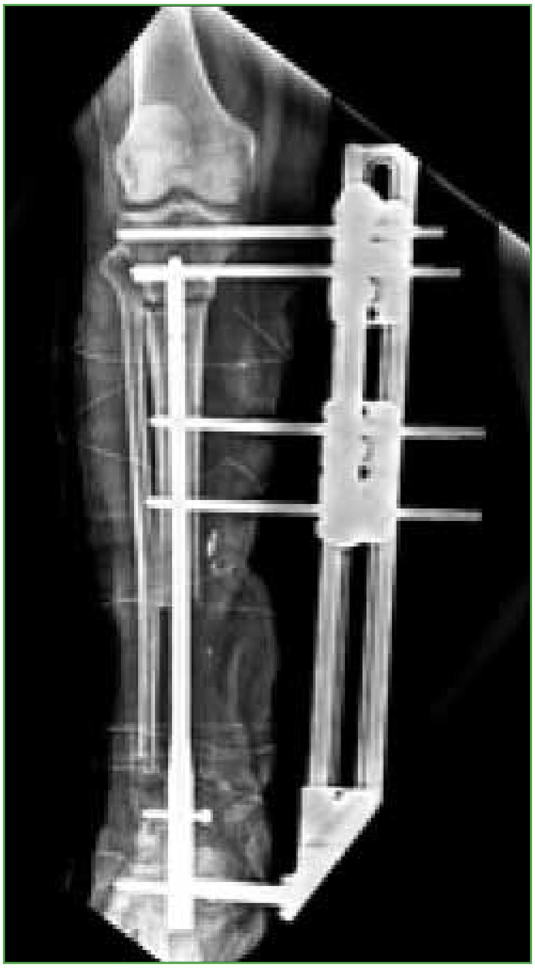

Figure 6. Anteroposterior radiograph of the right tibia and fibula. The observed metaphyseal-diaphyseal defect is treated with transport with uniplanar external fixator and intramedullary osteosynthesis.

Third stage

Once completed the bone transport, the patients proceed to the stage of compressing the coupling site (Figures 7 and 8). This was performed with the transport system or using a dynamic compression plate without invading the focus (Figure 9).

Figure 7. Anteroposterior radiograph of the right tibia and fibula. The end of the process of bone lengthening is observed.

Figure 8. Anteroposterior and lateral radiographs of the right leg. Consolidation once removed the external fixator is observed.

Figure 9. Anteroposterior and lateral radiograph of the left leg. Compression of the coupling site with a 6-hole DCP plate is observed.

FINDINGS

We analyzed 10 patients (3 women and 7 men) with osteomyelitis (3 cases) and open fractures (7 cases) who presented bone defects (Table 1). The average length of the treated defects was 9.75 cm (range 5-20), and the average rate of external fixation was 40.62 d/cm (range 36.5-54) (Table 2).

Table 2. Diagnosis and analysis of the results

Patient	Diagnosis	Defect (cm)	Rate of external fixation	Additional surgeries	Complications	ASAMI (bone)	ASAMI (functional)
1	Osteomyelitis	5	54	1	Yes	Good	Good
2	Exposed fracture	13	36	4	Yes	Poor	Poor
3	Exposed fracture	10	24	3	Yes	Good	Poor
4	Osteomyelitis	9	46.6	2	Yes	Good	Excellent
5	Osteomyelitis	7	42.7	2	No	Excellent	Excellent
6	Osteomyelitis	5.5	43.3	3	Yes	Good	Good
7	Exposed fracture	5	42	3	Yes	Good	Good
8	Exposed fracture	8	43.5	4	Yes	Poor	Poor
9	Exposed fracture	20	37.6	5	Yes	Poor	Poor
10	Exposed fracture	15	36.5	5	Yes	Poor	Poor

ASAMI = Association for the Study and Application of the Method of Ilizarov.

At the end of the reconstructive process, 50% of the patients had a good ASAMI bone score, 10% had an excellent score, and 40% had a poor score. The functional ASAMI score was excellent (20%), good (30%), and poor (50%). The 24% had a remnant infection.

Based on Paley's description of problems, obstacles and complications, in this series we observe:

- All patients reported eventual pain and difficulties sleeping or uncomfortableness with the distraction system.

- The obstacles —complications that require surgical intervention during the treatment— were replacements of Schanz pins owing to loosening, the most frequent complication (33%). Six Schanz pins suffered material fatigue in four patients; the mounting was subsequently changed, replacing two of them due to infection: Two patients (20%) required realigning the transport's axis, owing to deviations during the reconstructive process.

- Surgical debridement: Deep drainages were practiced on all patients to ensure that the focus remained sterile. The criterion to perform the drainage was the presence or absence of secretion from the wound, as well as other clinical and biochemical signs of infection (erythema, elevated local temperature, globular sedimentation rate, and C-reactive protein).

Complications

Minor complications were those which, though not solved, did not impinge on the final objective:

Misalignments: In our series, 60% of the patients presented some deformity at the end of the process, requiring surgery to correct the misalignment, based on deviations from the normal values (according to the ASAMI bone score) and difficulties in daily activity (Table 3).

Table 3. Magnitude of deformity, related to daily activity and performed surgery

Deformity	Magnitude of deformity	Daily activity	Surgery
Antecurvatum	+6°	Gait disturbance	Alignment
Equinus foot	Rigid Rigid Rigid	Gait disturbance Gait disturbance Gait disturbance	Achilles tendon lengthening Mobilization Achilles lengthening
Varus/Valgus	Valgus +7°	Without difficulty	Alignment
Recurvatum	+5°	Without difficulty	Alignment

- Two of these patients developed equinus stiffness, which required mobilization under anesthesia and lengthening by tenotomy.
- The rest of the deformities were a patient with a 6° antecurvatum, a patient with recurvatum, and one with valgus deformity, the magnitude and treatment of which are summarized in Table 3 and Graph 3.

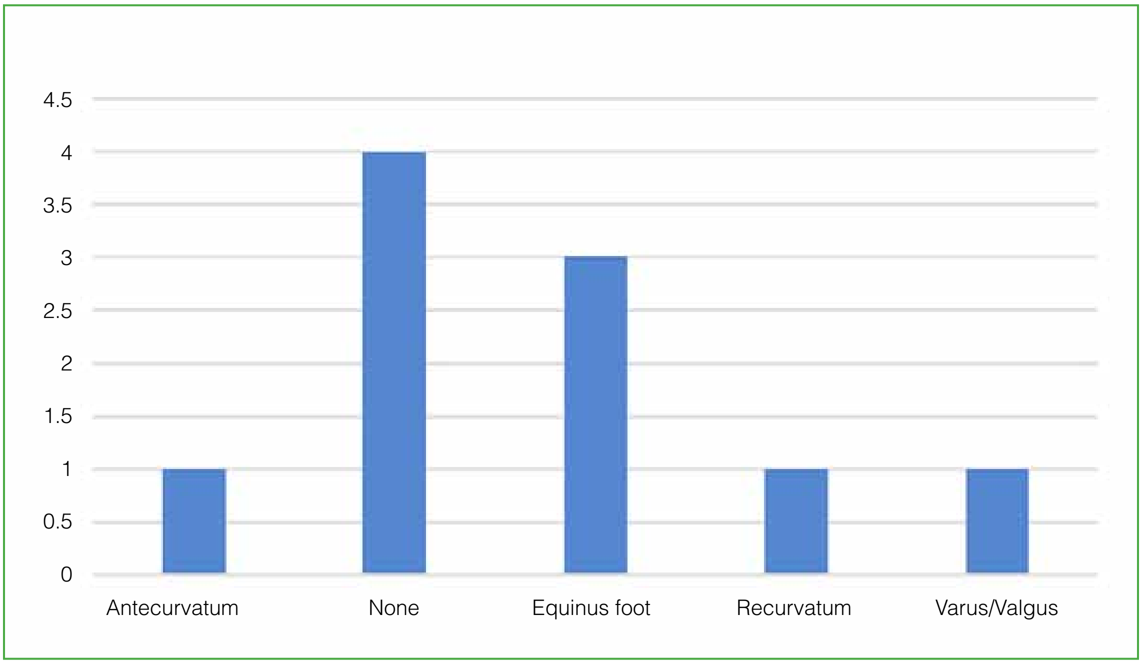

Figure 10. Deformities after the reconstruction process.

- One patient had to undergo above-the-knee amputation due to persistence of the deep infection, once concluded the reconstruction process (10%).

No major complications —i.e., those which are not resolved and preclude from attaining the final objective— occurred during surgeries. Finally, it was observed that the larger the defect's magnitude, the higher the number of surgeries required to complete the reconstruction. (Figure 11)

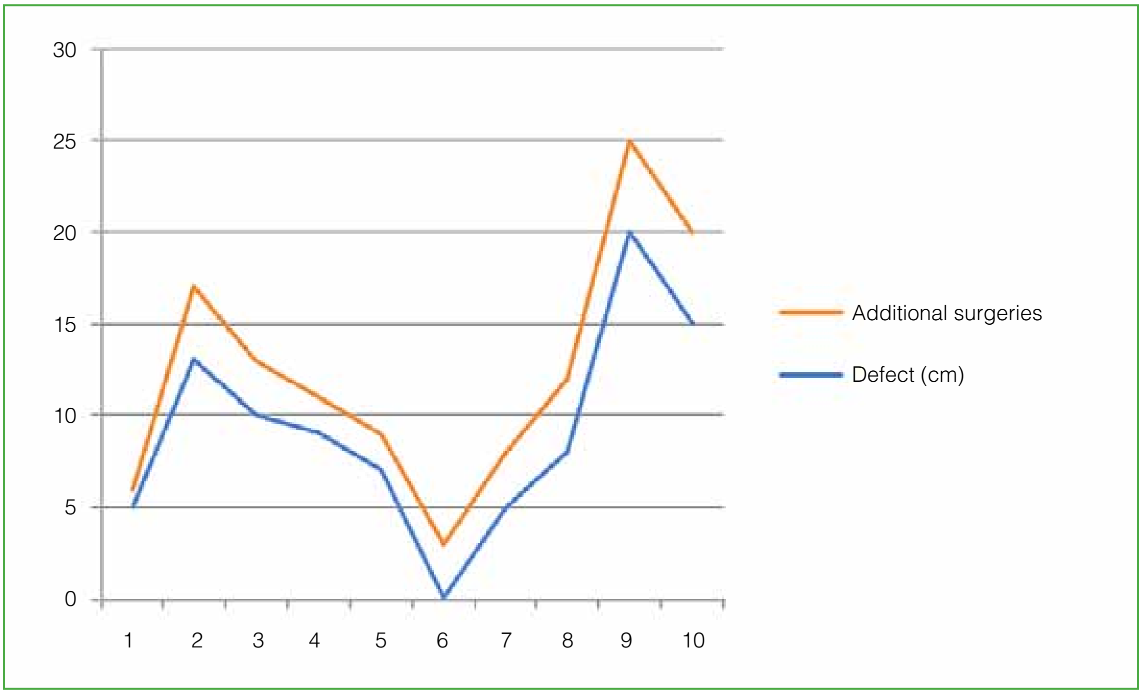

Figure 11. Relationship between the magnitude of the defect and additional surgeries.

DISCUSSION

This kind of procedure requires meticulously studying and selecting the patients. Mauffrey *et al.* described guidelines for patient optimization that make it possible to ensure an optimal biological environment for transport in bone defects, such as mechanical stability, favorable biological conditions (quitting tobacco, controlling blood glucose, nutritional streamlining), and managing endocrine metabolic changes. In a study by Brinker, patients were subjected to metabolic and endocrine tests; 80% of patients with pseudoarthrosis were reported as presenting anomalies —such as vitamin D deficiencies or thyroid and parathyroid hormones— which were not explained by any other cause.[12] In our center, the patients were treated by a multidisciplinary team to tackle these deficits on time, if required, although none of them had endocrine deficits.

Regarding the procedure's technical aspects, Mauffrey *et al.* describe the advantages of using external tutors on intramedullary osteosynthesis, as they allow for proper alignment and stability during the transport phase, reducing the misalignment rate to a minimum; furthermore, they make it possible to remove the tutor in earlier phases, assuming the risk of deep infections.[13]

Paley *et al.* carried out a comparative study (Ilizarov vs. transport on intramedullary osteosynthesis) and concluded that the transport with an external fixator on intramedullary osteosynthesis makes for considerably shorter times.[14] This would theoretically reduce the number of procedures by shortening distraction times and, hence, infection rates. This did not occur in our series, as all patients had to undergo at least one cleaning procedure due to clinical or biochemical signs of infection.

In their studies of transport on intramedullary osteosynthesis, Calder *et al.*[15] and Farsetti *et al.*[16] add a lower rate of misalignment and improved rehabilitation, besides the aforementioned findings. They also describe a lower rate of complications, such as stiffness in neighboring articulations (knee, ankle) or muscular contractures, thanks to the shorter usage time of the external fixator.

Comparing these theoretical advantages of alignment with intramedullary osteosynthesis, we can say that no clear benefits were observed in our series, considering the rate of misalignments at the end of the process. This may have been due to a lack of experience with this technique, since these complications are part of the learning curve. Even so, as regards speed, we consider our results to have been similar to those communicated in the bibliography, taking into account that we had to treat severe defects. In our series, the rate of external fixation was 40.62 days/cm, a lower result compared to the series of Kocaglu *et al.*, with a mean time of external fixation of 13.5 days/cm, and Li *et al.*, with 35.7 days/cm.[17]

In our series, the complications coincided with those of other studies, the infection associated to Schanz pins being the most frequent (33%), along with the need to apply soft tissue coverage procedures. Deep infection linked to the intramedullary implant constituted a 23%, a significantly higher rate than other series considered.

As described by Hosny, the results and the number of complications are mostly related to the magnitude of the defects and the surgical team's lack of experience. In our series, the average defect was 9.5 cm, which produces significantly greater complications.[18]

The limitations of this study are the small sample, the variability of the external fixation (80% unilateral, 20% circular), and its descriptive and retrospective character.

CONCLUSIONS

The use of external tutors guided by osteosynthesis constitutes a reliable method to treat bone defects, while infection is treated locally and systemically, reducing the times of the external tutor and, hence, of hospitalization and reoperation. In our series, the 50% obtained good and excellent functional results. Even so, these are demanding methods and are associated to a high rate of complications.

Conflict of interest: The authors declare no conflicts of interest.

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