Treatment of Tibial and Femoral Bone Defects with Bone Transport over an Intramedullary Nail

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Abstract

Objectives: To evaluate the results of the bone transport over an intramedullary nail (BTON) technique for the treatment of segmental bone defects.

Design: Retrospective review of case series.

Setting: Level 1 trauma center.

Patients/Participants: We included 40 patients who underwent reconstruction of the lower limb with BTON technique between 2000 and 2018. The technique was performed in the tibial segments in 21 patients and in the femoral segments in 19 patients.

Intervention: The surgical technique was performed in two stages for patients with infected nonunion. Infection was eradicated in all patients at the first stage. For the BTON at the second stage, monolateral external fixators and circular external fixators were used for femoral and tibial defects, respectively. In cases of defects without any infection, debridement with a single-stage BTON was performed.

Main Outcome Measurements: Complications as well as radiological and clinical results were evaluated according to the criteria of Paley-Maar.

Results: Minor complications occurred in 11 patients: pin site problems (nine), cellulitis (one), skin detachment due to Schanz screw (one). Major complications occurred in eight patients: docking site nonunion (four), early consolidation and Schanz screw failure (one), knee flexion contracture (one), ankle equinus contracture (two). Four patients had osteomyelitis as residual

sequelae. Bone score was excellent in 27 patients. Excellent functional results were obtained in 31 patients.

Conclusions: The BTON technique is associated with low cost because of the short treatment period, low complication risk, and rapid rehabilitation and is not limited by the amount of bone transport.

Level of evidence: Level IV

Key Words: bone transport over an intramedullary nail, segmental bone defect, infected nonunion.

Introduction

Treatment of patients with segmental bone loss using bone transport by external fixators (EFs) yields good clinical results. However, the long external fixation time (EFT) and consolidation time usually result in complications, including pin tract infections, deformities, and refractures.^{1,2} Bone transport over an intramedullary nail (BTON), which utilizes intramedullary (IM) nailing with EFs, could reduce EFT, thereby increasing stability and improving patient comfort.^{1,2} Herein, we aimed to clinically, radiologically, and functionally evaluate the results of the BTON in segmental bone loss of the tibia and femur.

Materials and Methods

Between 2000 and 2018, we retrospectively evaluated 44 patients with bone defects in the lower extremity who underwent reconstruction with BTON and/or simultaneous bone lengthening and were followed up for a minimum of 12 months. All operations were performed by two senior surgeons using a standard treatment approach. Four patients were excluded

because of inadequate follow-up data; finally, 40 patients (14 females and 26 males) were enrolled. BTON was performed in the tibial segments in 21 patients and femoral segments in 19 patients. Median age was 32 (16–78) years.

Twenty-six patients were diagnosed with segmental bone loss; the rest had infected nonunions. Six patients who had segmental bone defects created secondary to treatment of osteomyelitis were included in the segmental bone loss group. The average number of prior surgeries was 2.88 (0–6) for all defects (Table, Supplemental Digital Content 1, <http://links.lww.com/JOT/B35> which demonstrates patients' demographic).

Four patients with tibia defects had peroneal nerve injuries, of which two were secondary to gunshot injuries and the other two were whose peroneal nerves were sacrificed during treatment of malignant bone tumor resection (Table, Supplemental Digital Content 2, <http://links.lww.com/JOT/B36> which demonstrates etiology).

Local skin conditions, infections, smoking, limb length discrepancy (LLD), neurovascular status, and range of motion (ROM) of adjacent joints were recorded preoperatively and during follow-up. Total bone loss was calculated as the sum of bone defect length and loss of length, amount of lengthening or bone transport measured after bone resection. The EFT, external fixation index (EFI), consolidation time, consolidation index (CI), and follow-up periods were calculated. The CI of smokers and non-smokers was compared using independent sample tests. Radiological union was defined as ossification of three out of four cortices in plain X-rays. Complications and radiological and clinical results were evaluated as previously described (Table, Supplemental Digital Content 3, <http://links.lww.com/JOT/B37>).³ All patients were treated in accordance with the guidelines of the ethics committee of the department.

Surgical technique

The surgical technique was performed in two stages for infected nonunions.⁴⁻⁶ X-rays and orthoroentgenograms in both planes were obtained. Deformity analysis, LLD measurement, and paper tracing drawing were performed preoperatively. Osteotomy and resection levels, IM nail size, localization of additional locking holes for the transported segment, and interference screw location were determined by paper tracing. All IM nails were manufactured in a national medical company. Locking screws had a diameter of 4.8 mm and the locking holes had appropriate diameters. Custom-made nails were prepared considering these factors. Bone transport was performed with antegrade tibial IM nails in tibial bone defects and with retrograde calcaneotalotibial entry tibial IM nails in patients who required ankle arthrodesis. Retrograde femur IM nails in distal metaphyseal defects with femoral shortening and antegrade femoral IM nails in femoral bone defects without LLD were preferred.

First stage

In cases of infection with fistulas, methylene blue was administered through the sinus, and infected soft-tissue components were excised with a fish-mouth incision. All retained implants were removed. Debridement of the infected bone segment proceeded until bleeding bone margins (cortical paprika sign) were observed.⁵⁻⁷ Osteotomies were performed with multiple drill holes or a Gigli saw. The dead space and IM canal were filled with antibiotic-loaded polymethylmethacrylate (PMMA) beads and/or IM rods (Figure, Supplemental Digital Content 4, <http://links.lww.com/JOT/B38>). Large soft-tissue defects that could not be closed primarily were reconstructed by local rotational or free musculocutaneous flaps. The extremity

was stabilized with temporary EFs or braces. Culture and antibiogram tests were performed for the infected bone or/and soft tissues.

Second stage

After the first stage, laboratory tests, including leucocyte counts, C-reactive protein (CRP) levels, and erythrocyte sedimentation rates (ESRs), were performed and local infection findings were evaluated. The antibiotic-loaded PMMA in the dead space was removed through the mini-incision that was made during the first stage. Biopsy samples were obtained for frozen sectioning, gram staining, and culture in femoral and tibial defects. The absence of microorganisms and the presence of <5 neutrophils in 5 high-power fields (magnified 400×) indicated infection eradication.

Femoral defects: The guide wire was inserted into the proximal and distal IM canals using the piriformis approach for antegrade nailing or using the standard parapatellar approach for retrograde nailing. IM canals were over-reamed by 1.5 mm more than the custom-made nail diameter. Osteotomy was performed percutaneously with multiple drill holes. IM nail was inserted (Ortopro femur nail 4G for antegrade nailing/retrograde femur nail 4G for retrograde nailing, Ortopro Orthopaedics, Izmir, Turkey). Both proximal and distal bone segments were locked to the nail in patients without LLD. Only the distal part of the retrograde IM nail was locked in patients with LLD and planned simultaneous lengthening. Two or three 6-mm-diameter hydroxyapatite-coated Schanz screws were placed into each proximal, middle (transported), and distal bone segment perpendicular to both the sagittal and coronal anatomical axes and parallel to each other (at least 1 mm from the posterior aspect of the nail). Interference

screws were inserted especially in the metaphyseal bone segment to maintain the necessary amount of translation for anatomic alignment during the bone transport period. Schanz screws were attached to the monolateral EF (Orthofix LRS, Bussolengo, Verona, Italy / Dynafix EBI, Parsippany, NJ, USA).

Tibial defects: Osteotomy was accomplished using multiple drill holes or a Gigli saw after IM canal preparation. Antegrade custom-made IM tibia nail (Ortopro Tibia Nail 4G, Ortopro Orthopaedics Izmir, Turkey) was inserted. In patients planned for ankle arthrodesis, the nail's entry point was determined on the plantar aspect of the calcaneus by fluoroscopy. A threaded Kirschner wire was inserted along the subtalar and ankle joints to the tibia. After increasing the entry point size and IM canal preparation, tibial osteotomy was performed and the custom-made IM tibia nail inserted from the calcaneus retrogradely.⁴ Both proximal and distal bone segments were locked to the nail in patients without LLD. Percutaneous fibular osteotomy was performed before IM canal preparation in patients with LLD, who had planned bone transport and simultaneous lengthening. Only the distal part of the IM nail was locked to the bone; the proximal segment was left unlocked. A circular external fixator (CEF), one ring for each segment, was applied after nail insertion. In cases with ankle arthrodesis, a foot ring was attached to the frame. The long axis of the CEF and the IM nail had to be parallel in both the sagittal and coronal planes.

Treatment of uninfected defects

In cases of synovial pseudarthrosis, any remaining implants were removed. Soft-tissue reconstruction was performed, if needed. Synovial and fibrotic soft tissues and sclerotic bone

ends were excised. The BTON technique was applied as described in the second stages of femur and tibia defects.

Follow-up and EF removal

Pin site dressing was changed every 3 days. Physiotherapy of adjacent joints were initiated on the first postoperative day. Walking with full-weight bearing was allowed. Bifocal compression and distraction started on the seventh postoperative day at a rate of 0.25 mm (four times per day). Patients were followed-up every 2 weeks. X-rays were obtained to assess the distraction progress, new bone quality, the amount of lengthening and/or bone transport. Pin sites, neurovascular status, the ROM of the adjacent joints, and any signs of infection were examined.

When the desired amount of lengthening and/or bone transport was achieved, the transported segment was locked statically through additional locking holes, and the EF was removed (Figure, Supplemental Digital Content 5, <http://links.lww.com/JOT/B39> and 6, <http://links.lww.com/JOT/B40>). To reduce the risk of nonunion, we routinely performed docking site autograft from the iliac crest as our clinical experience increased after the initial cases. If needed, minimal plate osteosynthesis of the docking site was added to increase stability (Figure, Supplemental Digital Content 7, <http://links.lww.com/JOT/B41>). Patients were followed-up radiologically and clinically at monthly intervals.

Results

Soft-tissue reconstruction was required in eight tibia segmental bone defects during the first stage. Peroneal palsy was detected in four patients initially. Two of the patients were treated with ankle arthrodesis, and the remainder refused tendon transfer procedures followed by ankle foot orthoses. Table 1 shows the results.

Trifocal compression and distraction was performed in the tibia in only one patient, and the lowest EFI was 0.26 months/cm. Consolidation was achieved in 288.85 (63–492) days in all patients, while the CI was 1.07 (0.5–1.6) months/cm. Ten patients were smokers, and the mean CI was 1.22 (0.93–1.6) months/cm for the smokers and 1.02 (0.5–1.6) months/cm for the nonsmokers. The CI of the smokers was higher than that of the nonsmokers. Independent-samples test with a significance level of 0.05 revealed a significant difference between the two groups ($p=0.032$). The Paley-Maar bone score³ was excellent in 27 patients (Figure 1), good in two patients, fair in three patients, and poor in eight patients. For functional scoring, excellent results were obtained in 31 patients and good results in nine patients; no patient had fair/poor results. Table 2 shows the complications and bone and functional scores. Table, Supplemental Digital Content 8, <http://links.lww.com/JOT/B42> which demonstrates patient characteristics.

Discussion

Why is BTON preferred over all available bone transport techniques described in this section?

Bone defects may have different etiologies, and concomitant problems could lead to a challenging treatment. Amputation is an alternative treatment method for bone tumors when limb salvage is inappropriate, especially in Cierny Host C chronic osteomyelitis or in massive traumatic bone defects in mangled extremity injuries.^{3,7-9} Different reconstruction procedures

have also been described.^{8,10,11} Most treatments do not allow early weight bearing, and have limb lengthening and reconstruction limitations.

Acute limb shortening and relengthening as well as BTON procedures have been demonstrated using circular or monolateral EFs.^{1,2,12} Bone and/or soft-tissue defects are treated by shifting vascularized osteocutaneous tissue after an acute shortening technique. Thus, the gap zone is reduced, and soft-tissue reconstruction may not be needed. While osteosynthesis is maintained by compression on the shortened site, the shortening is compensated by lengthening the osteotomized metaphyseal site. This procedure has led to excellent results in most cases.^{9,12,13} If the length of acute shortening has to be increased, especially for defects >10 cm, a bone transport procedure is advised⁹; the long treatment duration with EFs alone may result in specific complications, including nonunion, infection recurrence, LLD, malalignment, and refracture.^{2,12,13}

Distraction and consolidation of the docking site represent the longest periods of the treatment. Although the BTON technique is more demanding than the Ilizarov method, it is preferred because of the short EFT. The presence of an IM nail allows early EF removal. The average EFI from different studies of bone transport using EFs only was 1.85 months/cm (Table 3). El-Rosasy¹² obtained an average lengthening of 4.2 cm for complicated fractures in patients with tibia defects and reported an EFI of 1.3 months/cm. Mekhail et al.⁸ performed bone transport with an average length of 5.7 cm in posttraumatic tibia and femur defects and reported an EFI of 2.2 months/cm. Eralp et al.² treated 28 patients with infected nonunion and obtained an average bone transport of 8.6 cm and an EFI of 1.87 months/cm. Sala et al.¹⁴ obtained an average bone transport length of 5.5 cm using bifocal compression-distraction and an average bone transport length of 9.7 cm using the double-level transport and reported an EFI of 2 months/cm

in all patients. In the study of Sen et al.,¹³ the average bone loss was 5.6 cm and the EFI was 1.4 months/cm. Tetsworth et al.⁹ reported an EFI of 1.8 months/cm for patients whose average bone defect length was 7 cm and who were treated with bone transport without acute shortening. However, in patients with an average bone defect length of 5.8 cm and who were treated with acute shortening and relengthening, the EFI was reported to be 1.7 months/cm. Bernstein et al.¹⁵ achieved 5.3 cm lengthening in posttraumatic bone defects in 30 patients using classical CEF and reported an EFI of 2.5 months/cm. The average EFI was 0.54 months/cm in patients who were treated with BTON, which indicates that the technique could provide a significant decrease in EFT and EFI.

Bone transport with locking plate was reported by Oh et al.¹⁶ for 10 patients who had infected post-traumatic segmental tibial defects of 5.9 cm, with the EFI 0.44 months/cm and BHI (CI) 2.15 months/cm, without any complication of malalignment, nonunion and infection. However, this technique was first described in limb lengthening patients who were not eligible candidates for IM nailing because of open physis or narrow IM canal or in cases avoiding the risk of avascular necrosis of the femoral head and blood supply disruption of the medullary canal for limb lengthening.^{17,18} Limb lengthening over plate, lengthening and plating studies showed decreasing EFI values. Some disadvantages and problems such as avoiding full weight bearing using a brace or cast; plate fracture and malalignment, especially varus in tibia and procurvatum in femur, have been reported.^{15,17,18,19} These disadvantages may be explained by the weaker biomechanical behavior of plates to the bending and axial forces compared with that of IM nails.

Another bone transport method is the cable bone transport procedure described to eliminate skin scar, pain and pin site complications without Schanz screws and K-wires.^{20,21,22} First, to avoid these complications vertically placed olive wires were used.²³ Quinnan et. al.²⁰ developed

the balanced cable transport technique with circular fixation and then 14 patients with large tibia bone defects underwent plating or IM nailing. EFI and CI of 7 patients, who comprised the subgroup of transport and then immediate nailing, were 0.36 months/cm and 0.75 months/cm, respectively, and all the patients underwent full weight bearing. Low EFI and CI were compatible with BTON results in addition to possessing the advantages of not having skin and pin site. Bernstein et al.²² described the surgical technique of BTON using cable and pulleys. The 14.5 cm massive tibial bone defect was treated successfully with EFI 0.41 months/cm without any complications; however, large case series are needed.

The EFI values from other studies on BTON range between 0.27 and 0.85, with an average of 0.55 months/cm,^{2,4,5,24-27} which is consistent with the EFI value in our study (0.54 months/cm). The average new bone CI in our study was 1.07 months/cm, while that in the other studies was 1.46 months/cm (range 0.86–2.15)^{2,5,24,26} (Table 4).

Advantages and disadvantages of BTON and its influence on EFI

The importance of the protection of endosteal bone circulation has been emphasized in the philosophy of distraction osteogenesis.²⁸ Reaming of the medullary canal and endosteum during the IM nailing procedure of the BTON does not extend the consolidation period.¹ Apparently, consecutive factors such as bone healing that occurs with new periosteal bone formation during the early stage of distraction,⁵ endosteal revascularization, increased stability and protection of the new bone from plastic deformation and fracture by the presence of IM nail, and early weight bearing allow for the compensation of medullary circulation loss due to reaming.^{1,2,4,25} We also believe that the consolidation period with BTON is short because of intramedullary reaming causing internal grafting.

Bifocal or trifocal bone transport is possible.^{2,24,29} Particularly, for defect length >10 cm, the trifocal transport method appears to be preferable to reduce the EFT, CI, and complication rate.^{3,29} In our study, the lowest EFI (0.26 months/cm) was determined in one patient who had undergone double-level transport, which was nearly half of that of the average EFI in all other patients. Vidyadhara and Rao²⁷ performed BTON to correct an average bone defect length of 11.65 cm in 27 patients who underwent giant-cell tumor resection of the tibia and femur; they used a double-level transport technique in 22 patients. A low average EFI (0.27 months/cm) was found in the 27 patients enrolled in the study.²⁷ Thus, trifocal transport method is preferred for long segmental bone defects.

Nonunion or delayed union and fracture at the docking site are the most common and specific complications of the bone transporting technique.^{2,3,8-10} The most likely causes are reduction of healing potency at the bone ends due to post-resection atrophy, the bone ends being surrounded by fibrocartilaginous tissue, and soft-tissue interposition at the docking site.^{9,29,30} The incidence of these complications is reduced with bone grafting.^{3,19,23,24,27,31,32} Paley³ and Tetsworth et al.⁹ encountered docking site healing problems in more than half of the cases and overcame this problem successfully by grafting. Retaining IM nails after EF removal also reduces the risk of these complications.^{2,4,24} Gulabi et al.²⁵ performed docking site bone grafting combined with BTON acute shortening and relengthening in five patients with nonunion tibia; union was achieved at all. We encountered these complications with our starting cases, which were solved by grafting the docking site in patients with nonunion and grafting with exchange IM nailing in patients with nail breakage secondary to nonunion. Reduction in the risk of nonunion was achieved by primary grafting of the docking site, which was performed in several patients at the time of EF removal, in addition to the increased clinical experience.

Some authors have performed minimally invasive plate osteosynthesis of the docking site or consolidation zone to prevent fracture or collapse.^{15,24,27} Herein, we obtained stability and compression at the docking site by locking the transported segment to the predrilled custom-made IM nail via the extra-locking holes.

Furthermore, the IM nail fixation technique is extremely difficult when the defect is too close to the joint line and when the proximal or distal segment is too short for IM nail locking.^{15,20,24} Therefore, the BTON is not suggested in these cases.

Effects of comorbidities on BTON

The most serious complication is bone infection. The presence of an infection before treatment increases the risk of further infection. Infection therapy is optimized with source control of the infected bone segment by radical debridement and with the achievement of a high, local bactericidal antibiotic concentration by antibiotic-loaded PMMA at the first stage.²⁹ Infection eradication was confirmed by normal CRP and ESRs values, normal frozen section, and negative culture specimen results at the end of a 6-week period. Therefore, the BTON technique is not contraindicated for patients with infections.^{5,24}

The potential disadvantages of a BTON are increased blood loss, IM infection, and fat embolism. IM infection is the most critical as it could result in the spread of pin tract infection to the medullary canal. Comorbidities, including problems with soft tissues and bone segments, old age, smoking, diabetes mellitus, presence of radiation scar, and immune deficiency, are the risk factors for infection.^{1,7,24} Although no significant difference in complications between smokers and nonsmokers was observed in this study, the CI appeared to be higher in smokers.

While several complications, including those due to operative intervention, occurred during the treatment period, patient satisfaction was high because the patients were able to return to their activities of daily living at the end of the treatment process.⁸ Although the functional results may not have been excellent in the end, we believe that the detailed information on the demanding process of limb salvage provided to the patients at the beginning of the study and the return to activities of daily living contribute to patient satisfaction.

This study has some limitations. First, this was a retrospective study and included a small number of patients. Second, a comparison of patients treated with different methods to determine success of the technique was not performed. So, comparative studies are needed. Lastly, the clinical and complication outcomes were obtained from the records of the two senior surgeons (MK, LE); thus, assessor bias was possible.

Conclusion

BTON is indicated for all patients with long bone defects without considering the amount of bone loss, excluding those with epiphyseal bone loss, elderly patients, smokers, and patients at high risk of infection because of systemic comorbidities or local, vascular problems.

While it is possible to transport bone segments using an internal segment transport system such as an intramedullary skeletal kinetic distractor nail or implantable motorized lengthening nails, with minimized risks of infection and soft-tissue problems, the cost is high and the amount of bone transport along the length of the implant is limited to 10 cm, whereas BTON can transfer bone segments up to 18.5 cm, thereby restricting the flexibility of the treatment.

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Figure Legends

Figure 1. A- A 38-year-old patient with segmental bone defect of femur. From left to right: final AP and lateral radiographs of the bone transport over an intramedullary nail technique (femur; the bone segment was transported distally) and clinical outcome. **B-** Final AP and lateral radiographs of the bone transport over an intramedullary nail technique (tibia) for the patient in Figure, Supplemental Digital Content 4, <http://links.lww.com/JOT/B38>; the bone segment was transported via circular external fixators.

Table 1. Results

	Overall	Tibia	Femur
Follow-up (months)	25.68 (12–64)	23.51 (12–56)	28.08 (12–64)
Initial shortness (cm)	3 (0–10)	2.26 (0–7)	3.82 (0–10)
Defect length after resection (cm)	7.09 (1–16.5)	8.36 (2.5–16.5)	5.68 (1–14)
Length of bone transport (cm)	9.44 (2–18.5)	9.24 (2.5–16.5)	9.66 (2–18.5)
External fixation time (day)	150.3 (32–358)	142.29 (32–237)	159.16 (34–358)
EFI (months/cm)	0.54 (0.26–1)	0.51 (0.26–0.72)	0.56 (0.33–1)
Consolidation time (days)	288.85 (63–492)	305.71 (120–489)	270.21 (63–492)
CI (months/cm)	1.07 (0.5–1.6)	1.17 (0.5–1.6)	0.97 (0.62–1.33)
Smokers/nonsmokers (n)	10/30	8/13	2/17
CI of smokers/nonsmokers (months/cm)	1.23 (0.93–1.6)/1.02 (0.5–1.6)	1.23 (0.93–1.6)/1.13 (0.5–1.6)	1.21 (1.08–1.33) / 0.94 (0.62–1.25)
Docking site graft (n)	21	13 ^a	8 ^b
Soft-tissue reconstruction (n)	8	8 [#]	0

[#]During the first stage, the following were needed: rotational fasciocutaneous flap in five patients, latissimus dorsi free flap in two patients, vacuum-assisted closure and a subsequent split-thickness skin graft in one patient.

EFI, external fixation index; CI, consolidation index

^aAllograft was used in two patients, and iliac autograft was used in 11 patients. Plate osteosynthesis was performed simultaneously in two of these 13 patients.

^bIliac autograft was used in eight patients. Plate osteosynthesis was performed simultaneously in two of these eight patients.

Table 2. Complications and bone and functional scores (according to Paley-Maar)

	Overall	Tibia	Femur
Docking site nonunion (n)	4	2	2
Complication (minor/major/sequelae)	11 ^a /8 ^b /4 ^c	6/4/3	5/4/1
Bone score (excellent/good/fair/poor)	27/2/3/8	14/1/1/5	13/1/2/3
Functional score (excellent/good/fair/poor)	31/9/0/0	15/6/0/0	16/3/0/0

^aGrade 1 and/or 2 pin site problems occurred in nine patients, and cellulitis occurred in one patient who was treated with repeated dressing changes and antibiotherapy.

Debridement and vacuum-assisted closure therapy were performed in one patient who had skin detachment after placement of the Schanz screws.

^bUnion was achieved in four patients (tibia, 2; femur, 2) who had a docking site nonunion and intramedullary (IM) nail breakage via grafting with IM nailing exchange. Schanz screw revision and recorticotomy were required in one of the patients who had bone transport over an intramedullary nail (BTON) in the femur because of early consolidation and Schanz screw failure. The degree of knee flexion in a patient with femur BTON was determined with quadricepsplasty. Percutaneous Achilles tendon lengthening was performed in two patients with ankle equinus contracture who were not treated with physiotherapy.

^cIM nail removal, debridement, and placement of antibiotic-impregnated IM rods were performed because of osteomyelitis in four patients (tibia, 3; femur, 1).

Table 3. Studies on bone transport with external fixation only

Study	EFI (months/cm)
Eralp et al. ²	1.87
Mekhail et al. ⁸	2.2
Tetsworth et al. ⁹	1.8 and 1.7
El-Rossey ¹²	1.3
Sen et al. ¹³	1.4
Sala et al. ¹⁴	2.0
Bernstein et al. ¹⁵	2.5
Average	1.85
Current study	0.54

EFI, external fixation index

Table 4. Studies on bone transport over an intramedullary nail

Study	EFI (months/cm)	CI (months/cm)
Eralp et al. ²	0.54	0.86
Eralp et al. ⁴	0.57	N/A
Kocaoglu et al. ⁵	0.45	1.06
Oh et al. ²⁴	0.85	2.15
Gulabi et al. ²⁵	0.40	N/A
Ferchaud et al. ²⁶	0.77	1.76
Vidyadhara and Rao ²⁷	0.27	N/A
Average	0.55	1.46
Current study	0.54	1.07

EFI, external fixation index; CI, consolidation index; N/A: not applicable