SUBSPECIALTY PROCEDURES

CLOSED DISTRACTION AND GRADUAL
DEFORMITY CORRECTION OF STIFF
HYPERTROPHIC TIBIAL NONUNIONS WITH
HEXAPOD EXTERNAL FIXATION

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Introduction

Closed distraction of stiff tibial nonunions with a hexapod external fixator can predictably lead to union without the need for additional surgery or bone graft.

Tibial nonunions are challenging to treat despite the frequency with which these complications are encountered. The associated morbidities include disuse osteopenia and joint contractures that complicate the management further and necessitate a treatment strategy that will allow early functional rehabilitation. Closed distraction with a hexapod external fixator for treatment of stiff hypertrophic tibial nonunion has the advantages of gradual correction of concomitant deformities, restoration of limb length, stability that allows early functional rehabilitation, and predictable union rates.

Preoperatively, all host factors that may impair healing should be addressed. Thus, preoperative measures should include cessation of smoking and excessive alcohol intake, good glycemic control in diabetics, and avoiding medications that impede bone healing. Intraoperatively, a fibular osteotomy is performed and a hexapod external fixator is applied with both rings orthogonal to the respective bone segments. The nonunion site is left undisturbed. Postoperatively, radiographs centered on the reference ring are obtained. A distraction program is then generated with the aid of the hexapod-specific computer software. The aim is to correct any mechanical axis deviation and, in addition, distract the nonunion site by 3 to 5 mm. A functional rehabilitation program, which should include weight-bearing mobilization, and pin-site care are then implemented. Assessment of successful union may be difficult, and a “trial of union” involving weight-bearing with the external fixator dynamized but still in place for several weeks is recommended before the fixator is removed.

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Indications & Contraindications

Indications

- Stiff hypertrophic tibial nonunion.

Contraindications

- Infected nonunion.
- Motion of $>7^\circ$ at the nonunion site following removal of all internal fixation and performance of the fibular osteotomy.

Step 1: Fibular Osteotomy

Resect 5 to 10 mm of the fibula, from its distal half or at the level of the fibular deformity if present.

- Position the patient supine on a radiolucent operating table. See Figure 1 for operating room setup with the instrument sets prepared.
- Under tourniquet control, approach the fibula between the peroneal and soleus muscles.
- Using a small oscillating saw, resect 5 to 10 mm of the fibula, from its distal half or at the level of the fibular deformity if present (Fig. 2).
- Close the fascia and skin in layers.
- Release the tourniquet for the remainder of the procedure.

Fig. 1

Fig. 2

Fig. 1 Operating theater setup with the image intensifier and instrument sets prepared.

Fig. 2 Resect 5 to 10 mm of the fibula.

Step 2: Application of Hexapod Proximal Ring Using “Rings First” Method

Apply the proximal ring orthogonal to the proximal bone segment.

- Using either half-pin or wire referencing, apply the proximal ring to the proximal bone segment (Fig. 3).
- To ensure orthogonal mounting, which is important to obtain the benefits from better frame mechanics and more accurate reductions, use fluoroscopic screening to align the ring perpendicular to the mechanical axis of the tibia in both the coronal and the sagittal plane.
- Once orthogonal mounting is confirmed (Figs. 4-A and 4-B), complete fixation with at least two 6-mm hydroxyapatite-coated half-pins and one 1.8-mm wire per ring/bone segment (Figs. 5-A and 5-B).
- Ensure sound surgical technique during half-pin and wire insertion to prevent pin-site complications later. The insertion should be as atraumatic and low energy as possible, with minimal iatrogenic damage to skin, soft tissue, and bone (Video 1).
- Always precede the half-pin insertion with predrilling through a protective drill sleeve and a small skin incision.
- As far as possible, avoid inserting the half-pins and wires in areas of considerable soft tissue, tendons, and tendon sheaths.

Fig. 3

Fig. 4-A

Fig. 4-B

Fig. 5-A

Fig. 5-B

Fig. 3 Proximal ring application using half-pin referencing.

Fig. 4-A Ensure perfect orthogonal mounting of the proximal ring to the proximal bone segment.

Fig. 4-B Radiographic confirmation of orthogonal mounting of the proximal ring.

Figs. 5-A and 5-B Proximal ring fixation completed with the addition of a tensioned fine wire and hydroxyapatite-coated half-pin.

Video 1 Video showing the “rings first” method of application of the hexapod external fixator for closed distraction of a stiff hypertrophic tibial nonunion.

Step 3: Application of Hexapod Distal Ring Using “Rings First” Method

Apply the distal ring orthogonal to the distal bone segment.

- Apply the distal ring in exactly the same manner and with the same precautions and imaging used for the proximal ring (Figs. 6 through 8).
- As a general rule the rings should be approximately 150 to 180 mm apart (Fig. 7-A).
- In cases with poor bone quality along with a very stiff nonunion, consider using ring-blocks in the proximal and distal segments.

Fig. 6

Fig. 7-A

Fig. 7-B

Fig. 8

Fig. 6 Distal ring application using wire referencing.

Fig. 7-A Ensure perfect orthogonal mounting of the distal ring to the distal bone segment.

Fig. 7-B Radiographic confirmation of orthogonal ring mounting of the distal ring.

Fig. 8 Distal ring fixation completed with the addition of 2 hydroxyapatite-coated half-pins.

Step 4: Connection of Struts and Application of Sterile Dressing

Connect the proximal and distal rings with 6 oblique struts.

- Complete the frame application by connecting the proximal and distal rings with 6 oblique struts (Fig. 9).
- At the end of the procedure, apply a sterile dressing to the frame. Note that the nonunion site is not disturbed at any point during the entire procedure.
- The patient is then returned to the ward for limb elevation (Fig. 10).
- Standard postoperative antibiotic prophylaxis is prescribed, per institutional sensitivity profiles, and administered for 24 hours after surgery.

Fig. 9

Fig. 10

Fig. 9 Frame application completed by adding 6 oblique struts.

Fig. 10 After application of a sterile dressing, the patient is returned to the ward to commence functional rehabilitation.

Step 5: Postoperative Planning, Deformity Correction, and Distraction

Perform gradual deformity correction and distraction at a rate of 1 mm per day

- Obtain postoperative planning radiographs with either the proximal or distal ring as the reference ring. To ensure accurate planning, the radiographs should be perfectly orthogonal and centered on the reference ring (Fig. 11).
- Any deformity present should be corrected through gradual distraction of the nonunion site at a rate of 1 mm per day. The aim is to achieve perfect mechanical alignment with at least 3 mm of distraction at the nonunion site (Fig. 12).
- No latency period is required and distraction can commence once the planning is completed.
- During this stage, a robust rehabilitation program under the guidance of a physiotherapist is established.

Fig. 11

Fig. 12

Fig. 11 Anteroposterior and lateral radiographs after frame application. (Reproduced, with permission, from: Ferreira N, Marais LC, Aldous C. Hexapod external fixator closed distraction in the management of stiff hypertrophic tibial nonunions. *Bone Joint J.* 2015 Oct;97-B[10]:1417-22. Figs. 2-A and 2-B.)

Fig. 12 Anteroposterior radiograph after deformity correction and 3 mm of distraction.

Step 6: Postoperative Care Until Union

Perform pin-site care and functional rehabilitation.

- Pin-site care consists of twice-daily cleaning with an alcoholic solution of chlorhexidine.
- Rehabilitation proceeds on an outpatient basis with an emphasis on normalization of gait.
- Outpatient follow-up is scheduled at 2-week intervals during the correction phase and until a robust rehabilitation routine is established. The interval between follow-up appointments is then increased to 4 weeks.

Step 7: “Trial of Union” and Frame Removal

Ensure adequate union prior to removal of the circular fixator.

- Once tricortical consolidation is evident radiographically, undertake a “trial of union.”
- First dynamize the fixator by releasing all 6 struts.
- If this does not cause any pain or deformity, ask the patient to bear weight.
- If the patient is able to walk without pain, he or she should then return home with the fully dynamized frame remaining in place for 2 weeks.
- If no deformity develops during this 2-week period, union is confirmed and the fixator can be removed (Fig. 13).
- As extraction torque values for hydroxyapatite-coated half-pins can be higher than the insertion torque values, it is generally advised to remove them with the patient under regional or general anesthesia.

Fig. 13

Fig. 13 Anteroposterior and lateral radiographs of united tibia after removal of the hexapod device. (Reproduced, with permission, from: Ferreira N, Marais LC, Aldous C. Hexapod external fixator closed distraction in the management of stiff hypertrophic tibial nonunions. *Bone Joint J.* 2015 Oct;97-B[10]:1417-22. Figs. 3-A and 3-B.)

Results

Hexapod closed distraction has been successfully used for the management of stiff hypertrophic tibial nonunions in our practice over the last 6 years. During this time, the technique was used for 67 tibial nonunions, 46 of which were described in our previous report¹. Sixty-six (99%) of the 67 were united after a mean of 24 weeks of use of the external fixator.

Pitfalls & Challenges

- Assessing the amount of motion at the nonunion site is vital and can be difficult to do prior to the fibular osteotomy. The final decision regarding the use of closed distraction for the management of tibial nonunions should be made only after all internal fixation has been removed and the fibular osteotomy has been performed.
- Orthogonal frame application allows the best biomechanical environment for healing of nonunions. Care should be taken in the operating theater to ensure orthogonal mounting of both the proximal and the distal ring to their respective bone segments.
- Early postoperative functional rehabilitation under the guidance of a physiotherapist is crucial for good results. It improves bone stock, limits joint contractures, and aids in healing of the nonunion site.
- Judging union can be challenging. A computed tomography scan of the nonunion site can be considered but might be difficult to interpret.

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Reference

1. Ferreira N, Marais LC, Aldous C. Hexapod external fixator closed distraction in the management of stiff hypertrophic tibial nonunions. *Bone Joint J.* 2015 Oct;97-B(10):1417-22.