

Evaluation of Compression in Intramedullary Hindfoot Arthrodesis

Lawrence Berson, M.D.*; William C. McGarvey, M.D.**; Thomas O. Clanton, M.D.**
Houston, TX

ABSTRACT

Compression was evaluated in an intramedullary hindfoot arthrodesis cadaver model using an external fixator and a "second generation" intramedullary compression nail. Four cadaver specimens were used. Four trials were done with each specimen.

Trial 1: manual compression with the 1st generation nail.

Trial 2: external fixator for compression with the 1st generation nail.

Trial 3: external fixator for compression with the 2nd generation nail.

Trial 4: nail-mounted compression device with the 2nd generation nail.

In Trial 1 it was not possible to obtain or maintain compression. In Trial 2 large values of compression were obtained with the external fixator, however compression was not maintained after the first generation nails were locked and the fixator was removed. In Trial 3 large values of compression were obtained with the external fixator, but minimal compression was maintained after the second-generation nails were locked and the fixator was removed. In Trial 4 large values of compression were obtained with the compression device and greater than 60% of the compression was maintained after the nail was locked and the compression device was released. The study revealed that both the external fixator and the compression device could produce compression. The external fixator is useful as an aid in the O.R. However, in

this study significant compression was maintained only with utilization of the compression device.

Key Words: Arthrodesis; Ankle; Compression; External Fixator; Intramedullary Nail; Tibiotalocalcaneal.

INTRODUCTION

Various fixation methods have been utilized for tibiotalocalcaneal arthrodesis (TTCA) including: multiple screws,^{12,14,15} pediatric blade plate,¹ and external fixation.^{6,9,15,25} Johnson⁸ popularized an intramedullary hindfoot nail in 1994 in conjunction with a posterior approach to the hindfoot.⁷ This technique has been modified using a lateral transfibular approach. Compression can be added to intramedullary hindfoot arthrodeses with the utilization of a femoral distractor.³ A "second generation" nail has been recently introduced with a nail mounted compression device. (Biomet, Warsaw, IN) Compression has been considered an essential factor in obtaining a successful ankle arthrodesis.²² We hypothesize that compression applied through a locked compression nail is more effective than compression applied either manually or with an external fixator at the time of tibiotalocalcaneal arthrodesis.

Compression across the ankle was evaluated using two different intramedullary hindfoot nails. An external fixator and a nail-mounted compression device were used to produce compression. Our goal was to apply and maintain compression across the ankle joint with intramedullary nail fixation, and assess the most reliable method to perform this.

MATERIALS AND METHODS

Fresh frozen below the knee specimens were obtained from four cadavers. The specimens were free of pathology at the ankle and subtalar joint, and were fully thawed prior to study. A lateral transfibular approach was used. The distal 10 cm of fibula was resected and flat cuts were made on the tibial and talus using an oscillating saw. The IMN was placed across the

Work performed at the University of Texas, Health Science Center, Houston, TX.

* The Greater Hartford Orthopedic Group, P.C., Hartford, CT.

** The Department of Orthopaedic Surgery, The University of Texas, Health Science Center, Houston, TX.

Corresponding Author:
Lawrence Berson, M.D.
Greater Hartford Orthopedic Group, P.C.
1000 Asylum Ave, Suite 2126
Hartford, CT 06105
Phone: (860) 728-6740
Fax: (860) 547-1554
E-mail: lljmb@highstream.net

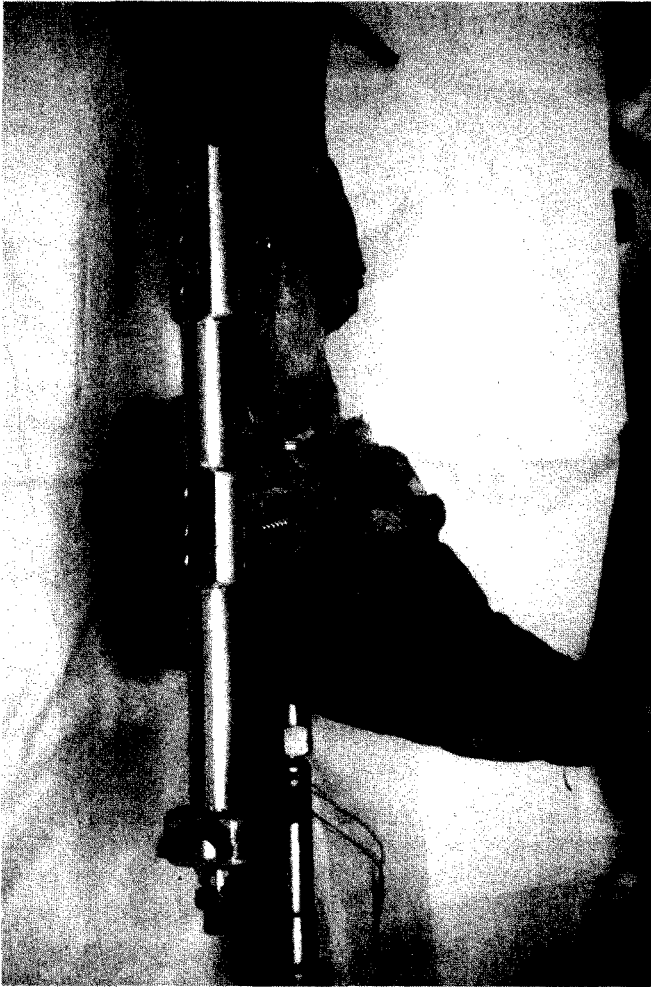


Fig. 1: Cadaver model with 2nd generation IMN and load washer in place.

ankle with a custom load washer between the tibia and talus and around the IMN as a washer (Fig. 1). The load washer was attached to a voltmeter calibrated to 1.15 pounds/mill volt. Initial measurements were obtained prior to compression to "zero" on the load washer. All measurements were recorded after pausing 10 seconds to allow for creep of the tissues. Compression across the ankle joint was produced with an EBI (Parsippany, NJ) articulating ankle external fixator with 4 DFS (EBI, Parsippany, NJ) bone screws or a nail-mounted compression device from an Ankle Arthrodesis Nail (Biomet, Warsaw, IN) (Fig. 2). Compression was applied maximally until hardware or bony deformation was noticed (Tables).

Four trials were done on each cadaver. In the first trial the Revision Nail was used (Smith & Nephew Richards, Memphis, TN) with manual compression, as described by Graves et al.⁵ This was done by locking the nail distally and then impacting the nail with a mallet and locking proximally.

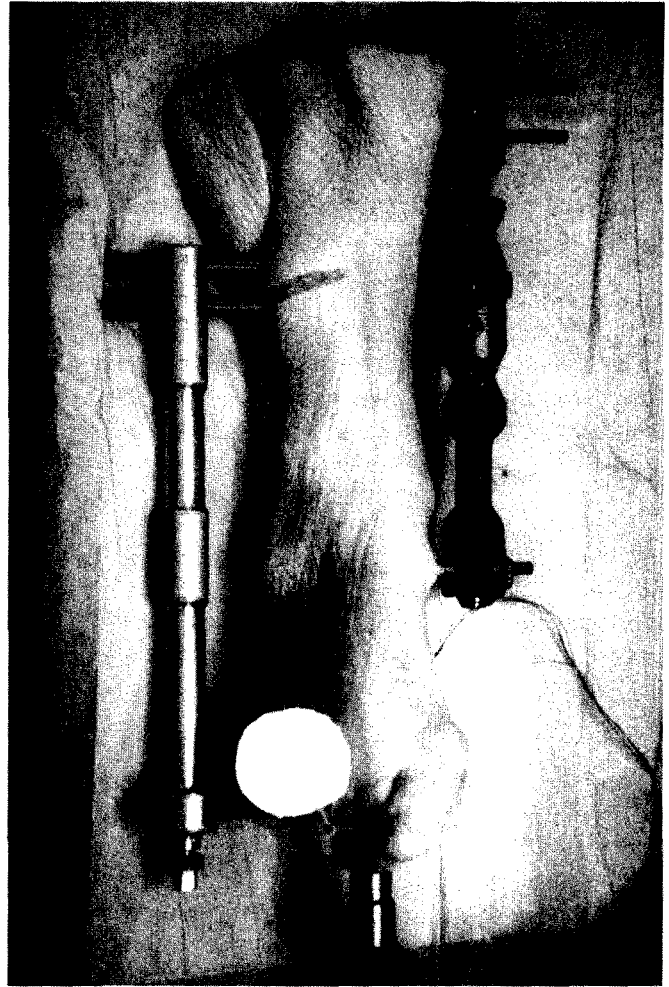


Fig. 2: Cadaver model with 2nd generation IMN and external fixator in place.

Trial 2 included the Revision Nail and the external fixator to provide compression. After the nail was placed and locked distally, the surfaces were compressed with the external fixator. The nail was locked proximally and the fixator was removed.

Trial 3 included the Ankle Arthrodesis Nail and compression from the external fixator. After the nail was placed and locked distally, the surfaces were compressed with the external fixator. The nail was locked and the fixator was removed.

Trial 4 included the Ankle Arthrodesis Nail using its nail-mounted compression device. This nail was inserted as described by Quill and Miller.¹⁷ The surfaces were compressed and the nail was locked.

In both nails the locking screws were 5 mm diameter and the rod locking holes were 5.5 mm in diameter. In all trials the nail was locked with four screws, two proximal and two distal and the fixator was removed. After each trial the load washer was zeroed to account for any deformation of the washer.

RESULTS

In the first trial compression was not obtained. The compression increased slightly when the jig was struck with the mallet but quickly returned to the baseline measurement (Table 1).

In Trial 2 large values of compression were obtained with the external fixator, however significant compression was not maintained after the nail was locked and the fixator was removed (Table 2).

In Trial 3 large values of compression were obtained with the external fixator. A minimal amount of compression, average 14%, was maintained after the nail was locked and the fixator was removed (Table 3).

In Trial 4 large values of compression were obtained with the compression device. An average of 60% of the maximal compression was maintained after the nail was locked and the compression device was released (Table 4).

After removing one locking screw the values decreased to an average of 26% of maximal compression (range, 25 to 33; average 28 lbs.), a loss of 34% of compression.

The compression maintained after use of the Ankle Arthrodesis Nail using its nail-mounted compression device (Trial 4) was significantly greater than that maintained after using external fixation with the Ankle Arthrodesis Nail (Trial 3) ($p=0.004$). The compression maintained after using external fixation with the Revision Nail (Trial 2) and the Ankle Arthrodesis Nail (Trial 3) was not significantly different. All statistical analysis was done using paired 1-tailed t-tests.

DISCUSSION

Compression has been considered an essential factor in obtaining a successful ankle arthrodesis²² and has been shown to enhance bone healing in a fracture model.²⁷ The amount of compression necessary for a successful arthrodesis has not been investigated. Compression may act favorably on an arthrodesis by improving contact of bone surfaces and stimulating bony healing. Clinical success has been reported with a T-plate arthrodesis that produced 25 pounds/inch of compression measured with strain gauges.^{21,22} An ankle arthrodesis technique using plates and a tension device to obtain compression¹⁹ has been shown to provide excellent stability, rapid union, and a 100% arthrodesis rate.¹⁹ We used a custom load washer to measure compression at the ankle joint during TTCA. Similar load washers have been used to measure compression in biomechanical studies of scaphoid fracture screw fixation.^{11,18} Compression was obtained using two devices, an external fixator as described by Donatto³

Table 1: Trial 1

Specimen	Compress	Finish
1	9	9
2	0	0
3	5	4
4	5	5

Table 2: Trial 2

Specimen	Compress	Finish
1	160	0
2	160	8
3	156	10
4	80	0

Table 3: Trial 3

Specimen	Compress	Finish
1	111	30
2	134	14
3	88	0
4	126	19

Table 4: Trial 4

Specimen	Compress	Finish	Minus Screw
1	88	48	22
2	110	69	29
3	90	60	23
4	80	45	25

and a nail-mounted compression device (Biomet, Warsaw, IN).

In this study both the external fixator and the nail mounted compression device produced compression across the arthrodesis surfaces. The Ankle Arthrodesis Nail using the external fixator maintained compression, however this was minimal. Compression maintained after the use of the Ankle Arthrodesis Nail and the nail-mounted compression device was significantly greater ($P=0.004$) than that maintained after using the external fixation with the same nail. This may be because the nail mounted compression device is in line with the nail. The external fixator may produce angular or rotatory torques as well as compression at the arthrodesis site and this could account for the large losses of compression after it was removed.

With the Ankle Arthrodesis Nail, a large amount of compression was lost after removal of one locking screw. This stresses the importance of using at least two locking screws at each end of the nail to help maintain compression. This may be due to the design of the IMNs with oversizing of the locking holes.

SUMMARY

The external fixator is an aid during TTCA, it enables the surgeon to position the foot and ankle in the appropriate position, compress the arthrodesis surfaces and concentrate on inserting the IMN. However upon removal of the external fixator only minimal compression was maintained. The Ankle Arthrodesis Nail ("second generation nail"), when used with its nail-mounted compression device, maintained significantly more compression at the arthrodesis site than when used with the external fixator.

REFERENCES

1. **Alvarez, RG; McKibbin, WK:** Tibiocalcaneal Arthrodesis Using Pediatric Blade Plate. *Oper Tech Orthop*, **6(4)**:217-221, 1996.
2. **Berend, ME; Glisson, RR; Nunley, JA:** A Biomechanical Comparison of Intramedullary Nail and Crossed Lag Screw Fixation for Tibiotalocalcaneal arthrodesis. *Foot Ankle Int.*, **18(10)**:639-643, 1997.
3. **Donatto, KC:** Technique Tip: Method to Facilitate Compression of Intramedullary Ankle Arthrodesis. *Foot Ankle Int.*, **18(4)**:247-248, 1997.
4. **Flemming, SS; Moore, TJ; Hutton, WC:** Biomechanical Analysis of Hindfoot Fixation Using an Intramedullary Rod. *J. So. Orthop. Assoc.*, **7(1)**:19-28, 1998.
5. **Graves, SC; Kile, TA; Lederman, R; Seligson, D; Henry, S:** Revision Nail Surgical Technique. Smith & Nephew Richards Inc. Memphis, TN, 1996.
6. **Johnson, EE; Weltmer, J; Lian, GJ; Cracchiolo, A:** Ilizarov Ankle Arthrodesis. *Clin. Orthop.*, **280**:160-169, 1992.
7. **Johnson, KA:** The Foot And Ankle: Master Techniques in Orthopaedic Surgery. New York, Raven Press, 1994, pp. 481-494.
8. **Kile, TA; Donnelly, RE; Gehrke, JC; Werner, ME; Johnson, KA:** Tibiotalocalcaneal Arthrodesis with an Intramedullary Device. *Foot Ankle Int.*, **15(12)**:669-673, 1994
9. **Kitaoka, HB:** Salvage of Nonunion Following Ankle Arthrodesis for Failed Total Ankle Arthroplasty. *Clin. Orthop.*, **268**:37-43, 1991.
10. **Lam, P; Myerson, MS; Alvarez, RG:** Tibiocalcaneal Arthrodesis for Unbraceable Ankle Deformity. Proceedings of the winter meeting of the American Orthopaedic Foot and Ankle Society, Anaheim, CA, 1999
11. **Lo, IKY; King, GJW; Milne, AD; Johnson, JA; Chess, DC:** Biomechanical Analysis of Intrascaphoid Compression Using the Herbert Scaphoid Screw System. *J Hand Surg.*, **23B**:209-213, 1998.
12. **Mann, RA; Chou, LB:** Tibiocalcaneal Arthrodesis. *Foot Ankle Int.*, **16(7)**:401-405, 1995.
13. **Moore, TJ; Prince, R; Pochatko, D; Smith, JW; Fleming, S:** Retrograde Intramedullary Nailing for Ankle Arthrodesis. *Foot Ankle Int.*, **16(7)**:433-436, 1995
14. **Papa, JA; Myerson, MS:** Pantalar and Tibiotalocalcaneal Arthrodesis for Post-Traumatic Osteoarthritis of the Ankle and Hindfoot. *J. Bone Joint Surg.*, **74A**:1042-1049, 1992.
15. **Papa, JA; Myerson, MS; Girard, P:** Salvage, with Arthrodesis, in Intractable Diabetic Neuropathic Arthropathy of the Foot and Ankle. *J. Bone Joint Surg.*, **75A**:1056-1066, 1993.
16. **Pinzur, MS; Kelikian, A:** Charcot Ankle Fusion with a Retrograde Locked Intramedullary Nail. *Foot Ankle Int.*, **18(11)**:699-704, 1997.
17. **Quill, G; Miller, S:** Ankle Arthrodesis Nail Surgical Technique. Biomet Inc. Warsaw, IN, 1999.
18. **Rankin, G; Kuschner, SH; Orlando, C; McKellop, H; Brien, WW; Sherman, R:** A Biomechanical Evaluation of a Cannulated Compressive Screw for Use in Fractures of the Scaphoid. *J Hand Surg.*, **16A**:1002-1009, 1991.
19. **Ross, SD; Matta, J:** Internal Compression arthrodesis of the Ankle. *Clin. Orthop.*, **199**:54-60, 1985.
20. **Russotti, GM; Johnson, KA; Cass, JR:** Tibiotalocalcaneal arthrodesis for arthritis and deformity of the hind part of the foot. *J. Bone Joint Surg.*, **70A(9)**:1304-1307, 1988.
21. **Scranton, PE; Fu, FH; Brown, TD:** Ankle Arthrodesis: A Comparative Clinical and Biomechanical Evaluation. *Clin. Orthop.*, **151**:234-243, 1980.
22. **Scranton, PE:** Use of Internal Compression in Arthrodesis of the Ankle. *J Bone Joint Surg.*, **67A(4)**:550-555, 1985.
23. **Shibata, T; Tada, K; Hashizume, C:** The results of arthrodesis of the ankle for leprotic neuroarthropathy. *J Bone Joint Surg.*, **72A**:749-756, 1990.
24. **Stone, KH; Helal, B:** A Method of Ankle Stabilization. *Clin. Orthop.*, **268**:102-106, 1991.
25. **Stuart, MJ; Morrey, BF:** Arthrodesis of the Diabetic Neuropathic Ankle Joint. *Clin. Orthop.*, **253**:209-211, 1990.
26. **Tabor, OB; Anderson, RB; Davis, WH:** Functional outcome of salvage arthrodesis of the ankle. Proceeding of the winter meeting of the American Orthopaedic Foot and Ankle Society, Monterey, CA, 1997
27. **Willenegger, H; Schenk, R; Muller, ME; Allogower, M:** Manual of Internal Fixation. New York, Springer-Verlag, 1970.