

Shell Brace for Stage II Posterior Tibial Tendon Insufficiency

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ABSTRACT

Background: The nonoperative treatment of posterior tibial tendon insufficiency (PTTI) can lead to unsatisfactory functional results. Short-term results are available but the impact on the evolution of the deformity is not known. To address these problems, a new brace for the flexible Stage II deformity was developed, and midterm followup was obtained. **Materials and Method:** In a prospective case series, eighteen patients (mean age 64.2 years; range, 31 to 82; four male, 14 female) with flexible Stage II PTTI were fitted with the new custom-molded foot orthosis. At latest followup of a mean of 61.4 (range, 20 to 87) months, functional results were assessed with the AOFAS ankle hindfoot score and clinical or radiographic progression was recorded. **Results:** The score improved significantly from a mean of 56 points (range, 20 to 64) to a mean of 82 points (range, 64 to 100, $p < 0.001$). Three patients (3/18, 16%) had a clinical progression to a fixed deformity (Stage III) and a radiographic increase of their deformity. All the other patients were satisfied with the brace's comfort and noted an improvement in their mobility. Complications were seen in three patients (3/18, 16%), and consisted of the development of calluses. **Conclusion:** The "shell brace" is a valuable option for nonoperative treatment of the flexible Stage II PTTI. Hindfoot flexibility was conserved throughout the observation period in all but three patients. Functional outcome and patient acceptance was above average. Problems were few, and closely associated with a progression to a fixed, Stage III deformity.

Level of Evidence: II, Prospective Case Series

Key Words: Posterior Tibial Tendon Insufficiency; Nonoperative Treatment; Shell Brace; Adult Acquired Flexible Flatfoot

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INTRODUCTION

Traditionally, the treatment of posterior tibial tendon insufficiency (PTTI) has been operative, and nonoperative treatment has been considered rather ineffective.^{7-9,14,15} As a result of advances in understanding the biomechanics of the flatfoot deformity and due to improvements in the quality of orthoses, nonoperative treatment has become a valid option.^{3,20} However, a variety of problems and patient complaints using these orthoses continue to be reported. The flexible Stage II PTTI lends itself well to orthotic correction, but high contact forces need to be transmitted during walking in order to maintain the corrected foot position and thus effectively unload the damaged posterior tibial tendon.^{12,17} Although good and excellent functional results in 77% of treated patients have been reported for the UCBL orthosis,^{5,11} low-profile orthoses stabilizing mainly the calcaneus and the arch frequently cause medial discomfort, pain and calluses, and lateral forefoot pain because of increased pressure. Ankle-foot-orthoses such as the Arizona AFO or the Maryland AFO have also been shown to improve pain and function,² and may cause less pressure concentration by partially transferring the forces to the leg. However, these orthoses are cumbersome to the patient, do not allow free walking and are therefore not well accepted. Furthermore, the medium to long-term performance of these devices is not known, specifically their continued ability to control the symptoms and inhibit progression of the deformity.

In an attempt to combine the advantages and comfort of a low-profile orthosis with the superior stabilizing effect and less arch discomfort of a high-profile orthosis, without its obvious disadvantages, a new medium-profile orthosis was developed. This study evaluates its immediate therapeutic effect and patients' acceptance, as well as the medium-term followup.

MATERIALS AND METHOD

Patients

Only patients with a flexible pes planovalgus due to Stage II posterior tibial tendon insufficiency (PTTI; Table 1)

were included, where all components of the deformity were fully correctable by manipulation, as well as the forefoot varus.^{12,17} All the patients complained about pain along the distal course of the posterior tibial tendon on weightbearing accompanied by an increasing deformity of the foot. No patient was able to accomplish painfree or repetitive single heel rise. No patient reported calcaneofibular impingement.

In a prospective case series, 23 patients were treated nonoperatively for Stage II PTTI with the “shell brace” at our institution between March 1996 and November 2006. The mean age of the patients was 64.2 (range, 31 to 82) years. There were four men and 14 women. Etiology of the PTTI was idiopathic, degenerative in 12 patients, traumatic in three, rheumatoid arthritis in one, poliomyelitis in one, and post-dissectomy syndrome in one. Comorbidities included obesity in seven patients (38%), high blood pressure in four (22%), and Type II diabetes in two (11%).

At the time of initial presentation, the symptoms of Stage II PTTI had been present for 29 (range, 8 to 72) months. All the patients had previously been treated with insoles, physical therapy and NSAIDs by the referring physician. These treatments were discontinued. All the patients with Stage II PTTI were strongly recommended to try nonoperative treatment first, except the young and very active patients, in whom the senior author felt that friction problems with the orthosis were very likely to make conservative treatment impossible (10 patients during the study period). An additional group of 17 patients was seen during the same period with Stage II disease that had not been previously treated with insoles. These patients had sufficient pain relief and control of the deformity with simple low-profile orthoses, and therefore received no further treatment. The AOFAS Ankle Hindfoot Score was used for functional assessment at first consultation and followup.¹³

Three patients were lost to followup and two were deceased due to unrelated reasons, leaving 18 patients. The followup was 61.4 (range, 20 to 87) months. Patients were

interviewed for comfort wearing the brace and time of daily use. Eight patients wore the shell brace in regular low shoes, while four patients walked more comfortably in a high top shoe, and six patients used an orthopedic boot. Aside from the AOFAS-score, changes of the patient’s mobility and complications using the brace were recorded. Any progression of the flatfoot deformity was assessed clinically and with weightbearing anteroposterior and lateral radiographs of the foot. To prevent bias, the patient’s radiographs taken at the initial and latest followup were reviewed by an orthopaedic surgeon (O.L.), who was not informed about the study’s purpose. Written informed consent for this study was obtained from all patients and the study was approved by the institutional review board.

Fabrication of brace

The patient was placed prone with the knee flexed at 90 degrees. All the components of the deformity were manually reduced and a cast mold was taken from the foot in this position. A model was taken from the cast, and further corrections were made on this model, as needed. The brace was built on this model. While the sole of the brace was made of 2-mm polypropylene, the socket was made of less rigid rubber and reached 1 to 2 cm beyond the malleolar level for increased support (Figure 1). For more comfort, the inserts were made of foam. To assure optimal tight-fitting of the contoured brace, a Velcro strip was attached to fasten the brace like a “shell” on the dorsum of the foot. Due to the large contact surface the pressure required for correction was widely distributed at the lateral wall of the calcaneus and at the medial longitudinal arch. Furthermore, the lateral border of the brace extends to the fifth metatarsal head preventing the forefoot from drifting laterally off of the brace. The brace could either be worn in a low shoe, a high top shoe, or a boot if additional stability was needed (Figure 2). In a boot with lateral and medial stabilizers a variant of the orthosis without coverage of the malleoli could be used.

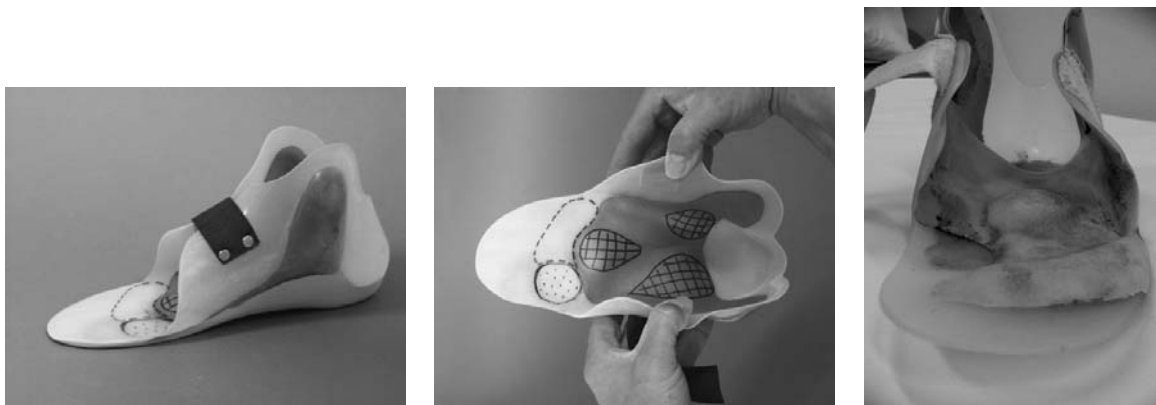


Fig. 1: The brace’s sole is made of 2-mm polypropylene; the socket is made of less rigid rubber and reaches 1 to 2 cm beyond the malleolar level for increased support. For more comfort, the inserts are made of foam. To assure optimal tight-fitting of the contoured brace, a Velcro strip is attached for fastening the brace like a “shell” on the dorsum of the foot (A and B). Note the accurate contour of the custom-molded sole (C).

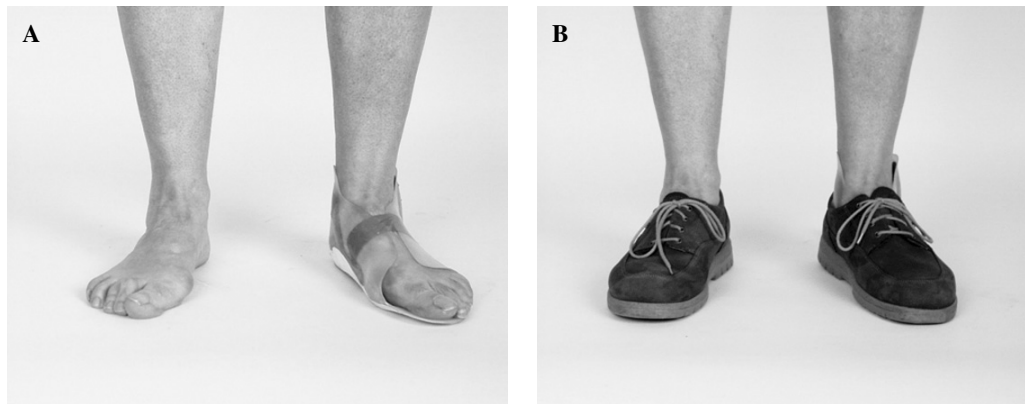


Fig. 2: The brace on a patient's foot closed with the Velcro on top for optimal tight-fitting (A). It can either be worn in a low shoe (B), in a high top shoe, or in a boot for additional stabilization.

Table 1: Classification of posterior tibial tendon insufficiency according to Johnson and Strom,¹² modified with Stage IV by Myerson¹⁷

Stage	Deformity	Clinical Findings
I	No deformity	pain along PTT, evidence of local inflammation
II	Flexible	weakness of PTT, too-many-toes sign, medial collapse, inability to do single-leg heel rise
III	Fixed	all signs of stage II, lateral calcaneal-fibular impingement, inability to fully invert foot
IV	Fixed	valgus talus tilt, ankle arthrosis

Statistics

A parametric statistical test (t-test for paired samples) was used for calculation of *p* values; *p* values less than 0.05 were considered to be significant. Correlations were analyzed using the simple linear regression model. Spearman's rank correlation coefficient *r* was interpreted as "poor" below 0.30, "fair" from 0.31 to 0.50, "moderate" from 0.51 to 0.60, "moderately strong" from 0.61 to 0.80, and "very strong" at or above 0.81.⁴ Descriptive statistics were based on survey results.

RESULTS

The mean AOFAS ankle hindfoot score improved significantly from 55.6 points initially (range 20 to 64) to 81.6 points (range 64 to 100) at latest followup (mean followup, 61.4 months, *p* < 0.001). The majority of patients (15/18, 83%) reported pain relief within 2.8 weeks (range, 1 to 8) once treatment had started. Ongoing minor discomfort along the medial arch with weightbearing was seen in 10 patients (56%). One patient with Stage II PTTI complained about lateral ankle pain at followup, which we attributed to calcaneofibular impingement. It resolved with proper fitting of the brace. The time of daily use was 12.1 (range, 8 to 14) hours corresponding to 84% of the patient's individual daytime. At the latest followup, 15 patients (83%) had distinctly less

pain when walking a few steps in regular shoes without the shell brace than before. Thirteen patients (72%) were able to perform some running and jumping in the brace. Ten patients (55%) were able to perform pain-free single leg heel rises at the end of the study. Two patients (11%) stopped wearing the brace because they were almost pain-free, one patient after 6 months and the other after 12 months of treatment.

Three patients (16%) felt persistent major discomfort wearing the brace and stated that the pain was not alleviated. Two of them discontinued wearing the brace (after 26 and 38 months) and complained about calcaneofibular impingement for the first time. One patient refused adjustment of the poorly fitting brace, but continued wearing it. However, no patient of our study group elected operative treatment.

Complications were seen in the three patients (16%) that had no pain relief wearing the brace. All of them developed calluses at the medial arch and two developed additional calluses at the fifth metatarsal base and the fifth metatarsophalangeal joint. The braces of these three patients were adjusted an average of 2.3 times (range, 0 to 4) without benefit. Aside from these patients, usually one adjustment of the brace was sufficient to correct any problem satisfactorily (mean, 0.8; range, 0 to 3).

At latest followup, three patients (16%, mean followup, 69.7 months; mean AOFAS ankle hindfoot score, 69.3 points.) were no longer considered as PTTI Stage II, but

to have had a progression to Stage III. These three patients were the ones who felt major discomfort wearing the brace and stated that their pain was not alleviated as mentioned above. Fifteen patient's feet (83%) remained supple after a mean followup of more than five years of nonoperative treatment with the shell-brace, and no restriction of ankle function and no onset or progression of hindfoot arthritis was recorded. In the three patients with progression to Stage III PTTI, the radiographic parameters describing the flatfoot deformity showed a tendency ($p = 0.072$) to an increased lateral peritalar subluxation on the anteroposterior view (from 26 to 31 degrees on average), and a tendency ($p = 0.063$) to an increased talonavicular or naviculocuneiform sag on the lateral view (talo-first-metatarsal angle, from 15 to 19 degree on average). No distinct radiographic progression of the deformity was recorded in the 15 patients with unchanged Stage II PTTI at latest followup. The calcaneal pitch angle did not change significantly in any patient.

A deterioration to Stage III PTTI with a fixed planovalgus deformity correlated moderately strongly ($r = -0.67$) to worse AOFAS ankle hindfoot scores, moderately strongly ($r = 0.71$) to the incidence of calluses in the medial arch and at the lateral border of the foot, and very strongly ($r = 0.84$) to major discomfort in the shell brace. For all patients, the correlation of worse functional results to obesity was fair ($r = -0.35$), and no correlation was found for age and outcome ($r = -0.12$).

Overall, the nonoperative treatment of Stage II PTTI with the shell brace led to good and excellent results in 15 of 18 patients (83%, mean AOFAS score 83.3 points, range 74 to 100). The mean AOFAS score of the remaining three patients with progression of PTTI was 69.3 points (range 64 to 74).

DISCUSSION

The goal of nonoperative treatment of the flexible, Stage II posterior tibial tendon insufficiency (PTTI) is to alleviate the patient's pain and to prevent or to postpone a progression of the deformity.^{16,20} The mechanism of action of the orthosis is to support the medial longitudinal arch, decrease the valgus angulation of the calcaneus and decrease the midfoot abduction.²⁰

The value of this treatment is particularly noticeable in elderly patients with a sedentary lifestyle, and in patients with concomitant health problems, but even younger and more active patients may benefit from a brace.¹¹ Several authors have recommended nonoperative treatment of PTTI as the first line of management, since for many patients this will be their only method of treatment.^{2,5,11,18,20} Operative treatment is complex and carries risks, and secondary problems including over- or undercorrection of the deformity and failure of a tendon transfer or soft-tissue repair.¹⁹ Wound healing problems are reported in up to one-third of patients.⁶

All the orthoses used for correction of a flexible PTTI act by reducing the dorsolateral peritalar subluxation. Lifting

the arch medially is the common factor. It will correct the talonavicular and naviculocuneiform sag and supinate the entire foot. Consequently the foot may slide off the orthosis laterally if not supported. If the supporting material is too soft, the correction cannot be maintained. Small corrections usually do not alleviate the patient's symptoms. Therefore a correction to almost neutral heel alignment is attempted, and the correction is maintained by rigid material not only for the shell embracing the foot, but also for the platform connecting the shell to the ground. Without a stable base, the shell would be allowed to rotate along the longitudinal axis of the shoe, producing pain through slippage and pressure points. With a tight fit from the heel to the dorsum of the foot, the shell brace maximizes the pressure distribution while maintaining correction. The support of the medial column has to drop rapidly distal to the naviculocuneiform joint, to keep the first metatarsal from being elevated and thus creating a lateral sliding force on the forefoot, resulting in pain along the lateral border of the forefoot. It is therefore crucial that the orthosis tries to "supinate" the hindfoot while "pronating" the forefoot, which is only possible in a truly flexible deformity. Failure to achieve this will cause painful pressure calluses along the fifth metatarsal, either due to inadequate fit of the orthosis, or to partial rigidity of the forefoot. The shell orthosis maximizes the support along the lateral border of the forefoot by extending to the fifth metatarsophalangeal joint.

In our study, nonoperative treatment of the flexible, Stage II PTTI with the shell brace yielded good and excellent results in 83% of patients (15/18). At the latest followup after more than five years functional results recorded by the AOFAS ankle hindfoot score were significantly improved.

The predominant complication of nonoperative treatment with the shell brace was discomfort at the medial longitudinal arch. In the majority of patients, this discomfort was alleviated with one adjustment (mean, 1.1; range, 0 to 4). However, in the three patients who experienced deterioration of the deformity to the fixed Stage III, adjustments of the brace for discomfort and calluses at the medial arch and the lateral border of the foot were not effective. A close correlation of the clinical and radiographic progression of the deformity to worse functional results, major discomfort at the medial arch, lateral border wearing of the brace, and the incidence of calluses were found in these patients.

The few reports on orthotic treatment of flexible flatfoot mainly involve the University of California Biomechanics Laboratory (UCBL) shoe insert and the Arizona ankle-foot-orthosis. The UCBL-orthosis is a thermoplastic in-shoe brace designed to limit subtalar eversion.¹⁸ It is molded with the heel in the neutral position and it exerts force at the lateral wall of the calcaneus and at the medial aspect of the longitudinal arch.¹⁸ It extends proximally below the distal tip of each malleolus, and extends laterally to half of the fifth metatarsal shaft. Medial posting is required to keep the heel in its neutral position and to maintain the transverse tarsal joints in a more rigid and corrected position.

Chao et al. treated 13 patients with a flexible PTTI with UCBL shoe inserts and an additional medial posting.⁵ The mean followup was 20 months. Seventy-seven percent had good to excellent results according to the author's own functional score, while three patients (23%) had fair and poor results and discontinued using the brace. Jari et al. treated 21 feet in 20 patients with flexible PTTI with UCBL orthoses.¹¹ After a mean followup of 24 months, the mean AOFAS ankle hindfoot score was 76 points. Two patients elected to have surgery but 82% of their patients were satisfied. No mention was made about an eventual progression of the deformity during the observation period.

The Arizona AFO is custom-molded leather and polypropylene brace that was designed for the treatment of PTTI.² While casting the mold for the brace, the calcaneus is reduced to its proper anatomic alignment underneath tibia and talus. It is a lace-in or Velcro-style brace and extends proximally to the mid-shaft of the tibia and distally to the metatarsal heads. Therefore, it stabilizes not only the hindfoot and the arch, but the ankle joint as well. The Arizona AFO has a low profile and can be inserted inside the patient's shoe.² Augustin et al. evaluated 21 patients with planovalgus deformity due to PTTI with Stage I (six feet), II (13 feet) and III (five feet) over a 2-year period.² The overall AOFAS ankle hindfoot score increased significantly from 38 points to 76 points with use of the Arizona brace. Unfortunately, the authors did not break down their functional results for the Stages I to III for a more appropriate comparison with our results. All the patients reported at least a moderate improvement in pain and function, except two patients with Stage II deformity. Again, the authors did not comment on progression of the deformity during the observation period.

In a prospective case series, Alvarez et al.¹ treated 47 patients with Stage I and II PTTI with a structured and supervised rehabilitation program and orthoses. Short articulated ankle-foot orthoses were used for more severe cases while foot orthoses (FO) similar to the UCBL orthosis were used for less severe cases. At followup of generally more than one year, most patients (89%) responded to this regimen of orthotic use and supervised physical therapy. Support of the foot and ankle with an SAAFO or FO was considered important while function was regained through the muscle-group ankle-strengthening program.¹

In a biomechanical evaluation of orthoses for PTTI, Imhauser et al. compared the UCBL, the MAFO (Maryland ankle foot orthosis) and the Arizona AFO in an in vitro model.¹⁰ The UCBL provided the best restoration of the flatfoot deformity. It was the only brace that partially restored kinematics at both the arch and the hindfoot. The MAFO, which is similarly structured, was not as effective in restoring arch and hindfoot kinematics because it was more loosely shaped at the medial and lateral borders of the foot. The Arizona AFO restored the height of the midfoot but not the talar height or calcaneal valgus angle. Most likely due to the rigid plastic support that was not reshaped to contour the

medial arch, the AFO shared some load of the heel that would normally be transferred to the medial arch.¹⁰ The Arizona AFO may interfere with the ankle joint's function due to its rigidity across the ankle and foot.¹⁰

The results of our study using the shell brace compare well to those of the other orthoses. In view of our very favorable early results—as soon as the patients were comfortable with the orthosis—we did not feel that physical therapy would have led to a more rapid, durable and relevant improvement of our patients' condition, in contrast to the study of Alvarez et al.¹ However, our study suggests that with longer followup (mean 61 months) some patients are found to have progression of the deformity to a Stage III, which has not been reported in the other studies with a maximum followup of 24 months. The three patients in our study who were seen to progress to a fixed deformity did not get adequate relief of symptoms wearing the orthosis. There were no initial clinical or radiographic characteristics that distinguished these patients from those in which the brace worked. This may suggest that patients whose symptoms do not improve substantially with nonoperative treatment despite initial flexibility of their deformity should be informed about their higher risk of progression to a fixed deformity. Whether this deterioration would have not occurred with initial operative treatment remains unknown.

Interestingly many of our patients reported an improvement of the weightbearing tolerance and stability (single heel rise) of their foot even when not wearing the orthosis. Although this has only enabled two patients to abandon the orthosis entirely, it may suggest some form of a stabilization of the degeneration of the tendon and the associated soft-tissue structures. The fact that some patients were able to run and jump with the orthosis underlines the anatomic fit and the optimum choice of orthotic materials.

The shell brace is similar to the UCBL in its design and construction. It achieves equal results regarding alleviation of the patient's discomfort, patient's acceptance, and low-profile appearance. Both allow reduction of the subluxated subtalar and transversal tarsal joints and preserve motion at the ankle joint. However, the shell brace has some distinct features. It extends proximally 1 to 2 cm beyond the malleoli, reaches distally to the metatarsal heads, and to the dorsum of the foot. The pressure against the medial arch and the lateral wall of the calcaneus required to correct the planovalgus deformity is distributed on a larger surface, which allows the shell brace to be built with a somewhat less rigid material while maintaining the desired correction. This is its main advantage, since patients frequently find highly rigid orthoses to be uncomfortable and prefer softer orthoses.¹⁹ Closing the shell brace with the Velcro-strip reduces slipping in the brace and allows adaptation to any swelling of the foot.

The strength of our study is the longer followup compared to previous conservative treatment studies. The main weaknesses are the small number of patients, and the absence of a control group.

CONCLUSION

Nonoperative treatment of flexible, Stage II PTTI with the shell brace is more than a temporizing measure prior to inevitable surgery. It is a valuable adjunct to the treatment choices for the flexible planovalgus deformity. The low profile appearance and the moderate rigidity of the brace in combination with the preservation of ankle motion resulted in high patient acceptance and allowed intermediate activity levels. Due to the reduction of the subluxated subtalar and transversal tarsal joints, durable conservation of the deformity's flexibility was achieved in the majority of the patients. The increase in weightbearing tolerance allowed some patients to perform lower demand daily activities even without the brace, and a few patients were able to walk free of pain even without the orthosis. Overall functional outcome was above average and the complication rate was low. Failure to respond to brace treatment correlated closely to a progression to the fixed, Stage III PTTI.

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