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Outcomes of the Bridle Procedure for the Treatment of Foot Drop

Jeffrey E. Johnson, MD1, E. Scott Paxton, MD2, Julienne Lippe, MD1, Kathryn L. Bohnert, MS4, David R. Sinacore, PT, PhD4, Mary K. Hastings, DPT, MSC1,4, Jeremy J. McCormick, MD1, and Sandra E. Klein, MD1

Abstract

Background: The purpose of this study was to determine the clinical outcomes and objective measures of function that can be expected for patients following the Bridle procedure (modification of the posterior tibial tendon transfer) for the treatment of foot drop.

Methods: Nineteen patients treated with a Bridle procedure and 10 matched controls were evaluated. The Bridle group had preoperative and 2-year postoperative radiographic foot alignment measurements and completion of the Foot and Ankle Ability Measure. At follow-up, both groups were tested for standing balance (star excursion test) and for ankle plantarflexion and dorsiflexion isokinetic strength, and the American Orthopaedic Foot & Ankle Society and Stanmore outcome measures were collected only on the Bridle patients.

Results: There was no change in radiographic foot alignment from pre- to postoperative measurement. Foot and Ankle Ability Measure subscales of activities of daily living and sport, American Orthopaedic Foot & Ankle Society, and Stanmore scores were all reduced in Bridle patients as compared with controls. Single-limb standing-balance reaching distance in the anterolateral and posterolateral directions were reduced in Bridle participants as compared with controls (P < .03). Isokinetic ankle dorsiflexion and plantarflexion strength was lower in Bridle participants (2 ± 4 ft·lb, 44 ± 16 ft·lb) as compared with controls (18 ± 13 ft·lb, 65 ± 27 ft·lb, P < .02, respectively). All Bridle participants reported excellent to good outcomes and would repeat the operation. No patient wore an ankle-foot orthosis for everyday activities.

Conclusion: The Bridle procedure was a successful surgery that did not restore normal strength and balance to the foot and ankle but allowed individuals with foot drop and a functional tibialis posterior muscle to have significantly improved outcomes and discontinue the use of an ankle-foot orthosis. In addition, there was no indication that loss of the normal function of the tibialis posterior muscle resulted in change in foot alignment 2 years after surgery.

Level of Evidence: Level III, retrospective comparative series.

Keywords: bridle, foot drop, peroneal nerve, tendon transfer, tibialis posterior tendon

Peroneal nerve injury is the most frequently encountered mononeuropathy in the lower extremity and a common cause of trauma-induced foot drop. Injury to the common peroneal nerve results in loss of function of the anterior compartment musculature of the leg and, often, the lateral compartment; it also results in foot drop and a steppage gate. The nerve can be injured by direct compression or traction. Common modes of injury include fractures about the knee, significant knee ligament injuries or dislocations, and compression or traction injuries as a complication of total knee or total hip surgery. Although an ankle-foot orthosis (AFO) with a fixed ankle joint or dorsiflexion assist ankle joint will improve function, it is often poorly tolerated in the younger, active population.

Although there has been limited success with nerve transfer for foot drop, the current standard for operative restoration of functional dorsiflexion in individuals with a peroneal nerve palsy is dynamic tendon transposition. Putti is credited as being the first, in 1914, to transfer the tibialis posterior tendon anteriorly through the interosseus membrane to the dorsum of the foot to restore dorsiflexion.
In 1954, Watkins et al reported “good” or “excellent” results in 24 of 25 patients using this technique.25 There have been many modifications of the tibialis posterior tendon transfer technique that have been subsequently described in the literature. Specifically, the Bridle procedure was designed to address under- or overcorrection of coronal plane position resulting from the surgeon’s choosing a point of attachment of the tibialis posterior tendon that was either too far lateral or too far medial, especially in the individual with spasticity. By the addition of 2 tendons to form an anastomosis of tendons with balanced attachment points on the foot, the pull of the tibialis posterior tendon was distributed more evenly to the dorsum of the foot, thereby avoiding a varus or valgus deformity from tendon overpull. This modification avoided the need for a triple arthrodesis or other procedure to stabilize the foot in neutral.

The purpose of this study was to provide a detailed description of the Bridle technique and to evaluate the outcomes of the procedure for traumatic peroneal nerve injury using clinical outcome measurements and objective physical function tests and strength measures to evaluate postoperative function. Based on reports of acquired deformity following tibialis posterior tendon transfer, a second aim was to determine if any postoperative deformity occurred through evaluation of standardized radiographic measurements.13,23,24,27

Methods

This was a retrospective case-control study. Institutional review board approval and consent from all participants were obtained. Participants were included who had undergone a Bridle procedure by 1 of 2 surgeons (J.E.J. or S.E.K.) for the treatment of foot drop caused by a traumatic isolated peroneal nerve injury from July 1, 2005, to April 1, 2010, providing for a 1-year minimum follow-up. Exclusion criteria included a concomitant diagnosis of neuromuscular disease, a partial common peroneal nerve palsy with 3/5 (antigravity) or greater strength in ankle dorsiflexion, tibial nerve palsy with posterior tibialis muscle weakness of 4/5 or less, nonambulation, or patient use of a walking aid prior to peroneal nerve injury. Ten participants without a history of foot or ankle injury were enrolled as a control group and were age, sex, height, and weight matched to our study participants.

All participants who met the inclusion criteria had an initial trial of nonoperative management. Some participants also underwent prior procedures, such as peroneal neurolysis, nerve repair, or grafting (acute or delayed). After failure of nerve function return, those individuals with a traumatic foot drop underwent a Bridle procedure to restore foot dorsiflexion.

Operative Procedure and Postoperative Management

The Bridle procedure performed in this group of participants was similar to the Rodriguez modification of the original Bridle procedure as described by McCall et al but modified by Rodriguez in 2 important details.12,20 Instead of a “subcutaneous” transfer of the tibialis posterior tendon at the anterior ankle, the tendon was transferred beneath the extensor retinaculum. Second, the tibialis posterior tendon was secured to the second cuneiform with an interference screw rather than sutures, staples, or a loop through the bone.7

First, a gastrocnemius-soleus lengthening was performed through an incision on the posterior medial calf on all participants who demonstrated a lack of passive ankle joint dorsiflexion of at least 5 degrees with the knee in extension. A Silfverskiöld test was performed to determine whether the gastrocnemius and soleus or just the gastrocnemius alone required lengthening.21

Second, the tibialis posterior tendon was detached from its insertion on the navicular tuberosity, and the often bulbus distal end was trimmed to the caliber of the remaining tendon and a grasping suture applied.

A third incision was made along the posterior medial border of the distal tibia to expose the tibialis posterior tendon in the deep posterior compartment. The tibialis posterior tendon was delivered into this incision.

A fourth incision was made over the tibialis anterior tendon just lateral to the tibial crest and above the ankle extensor retinaculum. All the contents of the anterior compartment were retracted laterally with the tibialis anterior tendon to expose the interosseous membrane. With a blunt Kelly clamp, the interosseous membrane was pierced, and the clamp was opened to create a slit in the membrane. This slit was then extended by blunt dissection distally as far as possible and proximally at least 10 to 15 cm to allow adequate space for transfer of the posterior tibialis muscle belly. The distal end of the tibialis posterior tendon was then transferred around the posterior surface of the tibia, through the opening in the interosseous membrane, and into the anterior compartment. While this maneuver was performed, great care was taken to avoid incarcerating or strangulating any of the components of the posterior compartment against the tibia as the tibialis posterior tendon was pulled through the interosseous membrane.

A fifth incision was made over the peroneal tendons along the lateral aspect of the distal leg. The peroneus longus tendon was transected in the distal third of the leg and the proximal end sutured into the peroneus brevis if the lateral compartment muscles were functional. If the peroneals were nonfunctional, the proximal end of the peroneus longus was allowed to retract.
A sixth incision was made over the peroneus brevis tendon, proximal to the base of the fifth metatarsal. The peroneus longus tendon was located inferior to the brevis tendon and pulled distally into this wound where a grasping suture was applied to the end. The distal end of the peroneus longus tendon was passed through a slit in the distal peroneus brevis tendon and then subcutaneously transferred in front of the fibula and under the extensor retinaculum into the anterior compartment alongside the tibialis anterior and transferred tibialis posterior tendons.

A seventh incision was made over the dorsum of the foot centered over the third cuneiform. The long extensor tendons were retracted laterally, and the muscle fibers of the extensor brevis were split and retracted medially with the deep peroneal nerve and dorsalis pedis artery to expose the dorsum of the second cuneiform. With the C arm, the middle of the second cuneiform was identified, and a drill hole (the same diameter as the distal posterior tendon) was made dorsal to plantar through the bone. The free distal end of the tibialis posterior tendon was then passed under the extensor retinaculum of the ankle and onto the dorsum of the foot into the area of the second cuneiform drill hole (Figure 1). A straight needle was used to pass the sutures in the tibialis posterior tendon through the drill hole and out the skin on the plantar foot. The foot was then placed in neutral to slight dorsiflexion, and the tibialis posterior tendon was then pulled distally into the cuneiform hole and tensioned to approximately 80% to 90% of its excursion and fixed in the second cuneiform with an interference screw (Figure 2A-2C). Tensioning of the tendon anastomosis was done superior to the ankle extensor retinaculum by pulling cephalad on the tibialis anterior and peroneus longus tendons to place equal tension on these medial and lateral stabilizing limbs of the transfer. Nonabsorbable sutures were placed to secure these tendons to the tibialis posterior tendon and to one another where they crossed through the slits in the tendons (Figure 2D).

Postoperatively, the patient was placed into a well-padded short-leg non-weight-bearing cast holding the ankle in neutral. The cast was bivalved in the operating room to prevent complications from swelling. Strict foot elevation was emphasized. The cast and skin sutures were removed at 10 to 14 days, and the foot was held in neutral while another synthetic cast was applied. Toe-touch weight bearing was allowed for the next 4 weeks. The cast was removed at 6 weeks, and the patient was placed into a removable walker boot and allowed to progress to full weight bearing as tolerated. Physical therapy was begun at this time for reeducation of the tibialis posterior tendon transfer with active and active assisted dorsiflexion and active plantarflexion. Precautions were given for avoidance of passive ankle joint plantarflexion until 3 months postoperatively. A night splint was worn until 3 months postoperatively to prevent premature stretching of the transfer. As swelling improved, a custom-molded AFO was fabricated, or the patient’s former foot drop AFO was worn in an athletic shoe to allow earlier discontinuation of the walker boot. The custom AFO or walker boot was used until at least 3 months postoperatively or until strength allowed discontinuation of the brace.

**Outcome Variables**

**Patient History.** Descriptive analysis of the participant sample was obtained from a chart review and history taken during testing, including the following: sex, age, etiology/mechanism of injury, site of injury (hip/pelvis or knee), preoperative nerve testing (if obtained) and attempted neurolysis, associated injuries, additional or prior procedures for associated injuries (including ligament and bony reconstructions for associated injuries), manual dorsiflexion and plantarflexion range of motion on a scale of 0 to 5, and passive dorsiflexion range of motion (ROM). Operative records were reviewed to identify additional procedures performed on the affected foot, intra- or postoperative complications, and the tourniquet time, if used.

The Bridle procedure was performed on 42 individuals from 2005 to 2011; 30 of these participants met study inclusion criteria (>1-year follow-up and foot drop related to traumatic isolated neurologic deficit). Nineteen Bridle participants (14 men, 5 women) and 10 matched controls (7 men, 3 women) agreed to participate and were evaluated with performance-based and self-reported measures of function at an average follow-up of 1.9 years (SD, 0.8). Demographic data are presented in Table 1.

Five Bridle participants had an injury at the level of the hip, while 14 had an injury at the level of the knee. Ten Bridle participants required knee ligament reconstruction/stabilization secondary to the initial injury. Three participants required pelvic and/or femoral stabilization; 1 required isolated femoral stabilization; and 1 required operative tibial stabilization as a result of the initial injury. Two participants had a nerve injury as a complication of a hip arthroplasty, and 1 participant had a nerve palsy as a complication of a Baker cyst removal. Two participants did not have other lower extremity reconstructive procedures, and the injury was a result of a gunshot in one and stretch injury from a fall in the other. Of the 19 Bridle participants, 16 had a previously attempted neurolysis of the peroneal nerve at the level of the knee, despite injury location.

Preoperative manual dorsiflexion strength prior to the Bridle procedure was 0 of 5 in all participants, with an average passive dorsiflexion of 1 degree. Six participants had concomitant procedures at the time of their Bridle. One had hardware removal from the ankle; 2 had lateral ankle ligament reconstruction; 1 had a flatfoot reconstruction; 1 had a dorsiflexion first metatarsal osteotomy with valgus-producing calcaneus osteotomy; 1 had a great toe interphalangeal joint fusion; and 1 had exostosis resection.
All participants completed a questionnaire measuring multiple outcome variables. Independent examiners administered these questionnaires. Participants completed the Foot and Ankle Ability Measure (FAAM), which asked for their perceptions of difficulty completing activities of daily living (ADL) and sport (eg, walking on even ground, walking up hills, stepping up and down curbs, running, cutting); the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Scale; and the Stanmore system questionnaire. Participants were considered to have excellent functional results with a Stanmore score of 85 to 100; good results, 70 to 84; fair results, 55 to 69; and poor results, less than 55.

The patient questionnaire also assessed the current level of function and satisfaction with questions regarding subjective current activity and pain levels using 0- to 10-point visual analog scales, current use of AFO and any assist devices (including their frequency), and overall satisfaction with the procedure. The participants self-rated the results of the surgery on a scale of excellent, good, fair, or poor.

**Range of Motion.** Passive dorsiflexion with knee extended and flexed, plantarflexion, subtalar joint inversion, subtalar joint eversion, and great toe extension ROM were measured by an experienced physical therapist using a universal full-circle goniometer as previously described. The subjects were positioned prone, with the hip extended and ankles off the end of the table. Dorsiflexion ROM with the knee extended and flexed to 90 degrees was measured with the axis of the goniometer placed over the lateral malleolus, with the moveable arm aligned with the fifth metatarsal shaft and the stationary arm aligned with the fibula. Subtalar joint inversion and eversion were measured with the stationary arm bisecting the leg and with the moveable arm aligned with the bisection of the calcaneus. Great toe extension ROM was measured with the stationary arm bisecting the medial side of the first metatarsal and the moveable arm bisecting the proximal phalanx of the great toe.

**Muscle Strength.** Ankle dorsiflexion and plantarflexor strength was assessed with the Biodex System 3 (Biodex Medical Systems, Shirley, NY) Pro Orthopedic Testing & Rehabilitation dynamometer at 60 degrees per second. Three trials were completed and the peak torque averaged.

**Star Excursion Balance Measure.** The star excursion test was used to assess standing balance. The participant stood on the involved side and reached with the opposite leg as far as possible in the anterolateral, lateral, and posterolateral directions. The participant lightly touched the furthest point possible on a tape-ruled line and then returned to a bilateral stance. The distance from the center of the grid to the touch point was measured in centimeters and normalized to the participant’s leg length.

**Radiographic Alignment.** Standing anteroposterior and lateral ankle/foot radiographs were obtained in a standardized manner and evaluated electronically in blinded fashion by the senior author (J.E.J.) using a precise and reproducible methodology previously reported. Sixteen Bridle participants had standardized standing preoperative radiographs that were compared to postoperative films. The lateral-view X-rays were evaluated for sagittal plane deformity by measuring the cuboid height (distance of the plantar-most aspect of the cuboid to a line joining the plantar fifth metatarsal head to the plantar calcaneus), Meary angle (angle between the line bisecting the talar head and neck with the line through the longitudinal axis of the first metatarsal, with positive values representing a line that has the apex on the dorsal side of the foot), and the calcaneal pitch (angle of plantar cortex of the anterior calcaneus, not including the calcaneal tuberosity, relative to the line from the plantar surface of the calcaneus to the fifth metatarsal head). Transverse plane alignment was measured with the Kite angle.

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**Figure 1.** This illustrates the tri-tendon anastomosis among the tibialis anterior, the transferred tibialis posterior, and the transferred peroneus longus tendons in a right foot. All the tendons are passed beneath the extensor retinaculum. Note that the tibialis posterior is transferred through slits in the tibialis anterior and peroneus longus, respectively, rather than via slits made in the tibialis posterior.
Participant characteristics between groups were compared with an unpaired t test for age and with a Fisher exact test for sex and race. An analysis of variance was performed to assess the similarity of the involved side for the Bridle and control groups for the majority of the following measures: ROM, muscle strength, balance, and radiographic alignment. Due to

**Statistical Analysis**

For measurements obtained for both limbs, sides for the control sample were randomly designated “involved” and “uninvolved” to achieve an equivalent proportion of left and right sides to that found in the Bridle group.

Figure 2. A, B. Once the tendons are passed and the tibialis posterior tendon is anchored into the second cuneiform, the tibialis anterior and peroneus longus tendons are tensioned equally by pulling cephalad on grasping sutures in each tendon while the tritendos tendon anastomosis is secured with sutures. C, D. The completed repair is shown with all redundant peroneus longus tendons removed.

For measurements obtained for both limbs, sides for the control sample were randomly designated “involved” and “uninvolved” to achieve an equivalent proportion of left and right sides to that found in the Bridle group.
violations of the assumptions required for the statistical method used, for dorsiflexion knee flexed ROM, great toe extension ROM, subtalar joint inversion and eversion, ankle dorsiflexion strength, and transverse plane alignment required rank transformation prior to analysis.

Wilcoxon rank-sum test was used as a nonparametric alternative for between-group comparison of the FAAM, AOFAS, and Stanmore questionnaire. Paired t tests were performed to assess differences between preoperative and postoperative FAAM, transverse plane alignment, and Meary angle. A nonparametric signed-rank test was used to compare the preoperative and postoperative cuboid height and calcaneal pitch.

Within the Bridle participant group, Spearman correlations and associated P values were used to assess the association of select continuous variables with the FAAM (total percentage ADL and sport). The associations of certain characteristics and FAAM scores were assessed with unpaired t tests or Wilcoxon tests. The data analysis was generated with SAS (SAS Institute Inc, Cary, NC). P ≤ .05 was considered significant for all comparisons.

Results

Of the 19 participants, 16 required a gastrocnemius-soleus lengthening during the procedure. There were no intraoperative complications. Four months postoperatively, 1 participant ruptured the tibialis posterior tendon at the anterior ankle requiring revision with repair and augmentation with the peroneus tertius tendon. This participant initially had the peroneus longus tendon woven through a split in the tibialis posterior tendon, which may have weakened the tibialis posterior tendon predisposing it to rupture. This occurred early in the series, and the majority of participants underwent a slightly modified technique as described above where the posterior tibialis is woven through a slit in the peroneus longus.

Outcome Scores

The average postoperative FAAM ADL subsection score for the Bridle group was significantly lower than that of controls (87% ± 12% vs 99% ± 2% for controls, P < .01). For the sport subsection, the Bridle group scored 65% ± 17%, compared to 98% ± 2% for controls (P < .01). Ten Bridle participants had completed preoperative FAAM questionnaires and were compared with their postoperative scores. The ADL and sports subsection scores demonstrated a significant improvement from preoperative to postoperative measurement (ADL: 67% ± 17% vs 86% ± 9%; sports: 22% ± 16% vs 59% ± 18%, respectively; P < .01). No correlation was found between FAAM scores and age, location of injury, gastrocnemius-soleus lengthening, plantarflexor strength, or dorsiflexion ROM.

The average AOFAS score was 80 ± 13 for the Bridle group, compared to 96 ± 5 for controls (P < .01). Average Stanmore scores for the Bridle group were 78 ± 14 (good result) and 98 ± 3 (excellent) for the controls (P < .01).

Subjective Outcomes

All Bridle participants reported that they were satisfied with the procedure (19 of 19). Twelve participants reported an “excellent” self-reported outcome, and 7 had a “good” outcome. The average visual analog scale pain score was 2.7. No participant required the use of an AFO for everyday activities; however, 2 participants reported use of an AFO for athletic activities.

Objective Testing

Plantarflexion ROM was significantly reduced in the Bridle group (30 ± 10 degrees) compared to controls (39 ± 8 degrees, P < .01; Table 2). Dorsiflexion and plantarflexion strength was significantly reduced in the Bridle group versus the control (dorsiflexion: 2 ± 4 vs 18 ± 13 ft·lb, P < .01; plantarflexion: 44 ± 16 vs 65 ± 27 ft·lb, P < .02). Standing balance as measured by the star excursion test was reduced in Bridle participants as compared with controls in all directions of reach (P < .05).

Radiographic Analysis

There were no significant differences found between the pre- and postoperative radiographs. There were no differences between the postoperative measures of the Bridle participants and the controls (Table 2).
The first clinical series of the Bridle procedure was reported in 1991 by McCall et al, who attributed this technique to D. C. Riordan, MD, and Paul Brand, MD, for the treatment of the equinus and equinovarus deformities associated with cerebral palsy, Charcot-Marie-Tooth disease, Guillain-Barre disease, lumbar myelodysplasia, and peroneal nerve injury. In total, 128 Bridle procedures were performed on 101 patients: 80 had cerebral palsy, and only 2 had a peroneal nerve injury. The procedure was initially described as an anterior transfer of the tibialis posterior tendon through the interosseous membrane and subcutaneous transfer of the distal stump of the peroneus longus tendon over the anterior ankle, with a tri-tendon anastomosis among the tibialis posterior, tibialis anterior, and peroneus longus tendons in the distal leg above the ankle extensor retinaculum and an Achilles tendon lengthening. Approximately 75% of all individuals had a good or excellent result, with the cerebral palsy group faring the best, with 80% good to excellent results despite only 74% of them becoming brace free postoperatively. There was an overall 21% complication rate, of which a calcaneus deformity was the most common, especially in the cerebral palsy group, requiring 12 reoperations. There were 4 cases of an acquired pes planovalgus deformity following the Bridle in the cerebral palsy group, all of which required a hindfoot arthrodesis.

The procedure was later modified by Rodriguez to include a transfer of the insertion of the tibialis posterior tendon into the second cuneiform to provide a secure tendon to bone insertion and a direct line of pull. He reported on 10 patients, all of whom became brace free.

### Table 2. Study Measure Comparisons

<table>
<thead>
<tr>
<th>Measure</th>
<th>Bridle, n = 19</th>
<th>Control, n = 10</th>
<th>P Value</th>
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<tbody>
<tr>
<td><strong>Range of motion, degrees</strong></td>
<td></td>
<td></td>
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<tr>
<td>Dorsiflexion</td>
<td></td>
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<tr>
<td>Knee extended</td>
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<td>8 ± 5</td>
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<tr>
<td>Knee flexed</td>
<td>13 ± 4</td>
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<tr>
<td>Plantarflexion</td>
<td>30 ± 10</td>
<td>39 ± 8</td>
<td>.01</td>
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<tr>
<td>Great toe extension</td>
<td>50 ± 16</td>
<td>61 ± 16</td>
<td>.11</td>
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<tr>
<td>Subtalar joint</td>
<td></td>
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<tr>
<td>Eversion</td>
<td>7 ± 2</td>
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<tr>
<td>Inversion</td>
<td>12 ± 4</td>
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<tr>
<td><strong>Strength, peak torque (ft·lb)</strong></td>
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<tr>
<td>Ankle dorsiflexion</td>
<td>2 ± 4</td>
<td>18 ± 13</td>
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<tr>
<td>Ankle plantarflexion</td>
<td>44 ± 16</td>
<td>65 ± 27</td>
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<td><strong>Star excursion balance test</strong></td>
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<tr>
<td>Anterolateral</td>
<td>0.77 ± 0.08</td>
<td>0.85 ± 0.09</td>
<td>.03</td>
</tr>
<tr>
<td>Lateral, out to side</td>
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<tr>
<td>Posterolateral</td>
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<tr>
<td>Meary angle, degrees</td>
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<tr>
<td>Cuboid, mm</td>
<td>12 ± 3</td>
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<tr>
<td>Calcaneal pitch, degrees</td>
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<td>24 ± 4</td>
<td>.94</td>
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<tr>
<td>Transverse plane, degrees</td>
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<td>.16</td>
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<tr>
<td><strong>Radiographic alignment</strong></td>
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<tr>
<td>Meary, degrees</td>
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<td>Transverse plane, degrees</td>
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<td>.48</td>
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*Values presented in mean ± SD.

Reach distance normalized to leg length.

Postoperative vs control.

Pre- vs postoperative Bridle subjects.
tendon-to-tendon connection and resultant decrease in active dorsiflexion.\textsuperscript{12,19} These previous small case series provide useful information, but few details of the operative technique are reported. Clinical outcomes and objective measures are rarely discussed.

The results of this case-control study support the use of the Bridle procedure to restore ankle dorsiflexion function and strength for treatment of traumatic foot drop in the setting of a peroneal nerve injury. The satisfaction rate was high, with 100% good or excellent self-reported outcomes and 100% brace free for normal daily activities or walking, although 2 of 19 required an AFO for athletic activities.

Based on standardized weight-bearing radiographs, this study is the first to confirm that there were no changes in static stance foot alignment measures 2 years postoperatively. There is concern from previous reports that loss of the tibialis posterior as a support for the longitudinal arch and inverter of the foot may lead to changes similar to those seen in adult-acquired flatfoot, exhibited by an increased calcaneal eversion, decreased plantarflexion of the forefoot, and lowering of the arch.\textsuperscript{16,17,22} Previous studies using visual appraisal and plantar pressure assessment found that 6% to 30% of individuals had increases in medial plantar pressure and 8% to 19% had an increase in calcaneal valgus or other alignment associated with a flatfoot.\textsuperscript{11,12,14,24} Worsening in bony alignment was not found in this study. Our findings did not reflect a risk for loss of arch height after this procedure.

The Bridle procedure improved the average sports and ADL subsections of the FAAM by 19% and 37%, respectively. However, despite this improvement, the postoperative FAAM scores were significantly lower in the Bridle group for both subsections when compared with the matched controls.

There is only 1 prior report on the Bridle procedure using the technique described in this study, which included patients with foot drop from multiple etiologies. Rodriguez reported on 11 procedures among 10 feet for various causes of foot drop.\textsuperscript{20} All were brace free at an average of 6.5-year follow-up, and he found better results with regard to degree of active dorsiflexion in those patients with a traumatic etiology.\textsuperscript{20} Although Rodriguez did not report his results using validated outcome measures, objective testing, or comparison with controls, the results were similar to this current study. All 19 Bridle participants in our study were brace free for their normal daily activities.

Previous reports on tendon transfers for foot drop described similar outcomes. In 1967, Carayon et al reported “good” or “excellent” results in 22 of 31 patients with a dual transfer (tibialis posterior tendon to tibialis anterior tendon and the flexor digitorum longus tendon to both the extensor hallucis longus and extensor digitorum longus tendons).\textsuperscript{1} Vigasio et al recently reported on a modification of this procedure in which the tibialis anterior insertion was changed to the third cuneiform to provide an optimal traction line for maximal dorsiflexion. At 2-year follow-up, 81% of their patients exceeded 0 degree of dorsiflexion and had a balanced foot posture, and 87.5% had abandoned the use of an AFO.\textsuperscript{24} These authors also transferred the flexor digitorum longus tendon to the extensor hallucis longus and the extensor digitorum longus.\textsuperscript{24}

Prahinski et al reported on outcomes at an average 5-year follow-up after the Riordan Bridle procedure in 10 soldiers (8 of whom had traumatic peroneal nerve injury). They found that while 5 patients returned to running initially, only 2 were able to keep running. While 9 patients were brace free initially, only 5 remained so at final follow-up. Only 3 patients returned to active duty, with 2 having no detectable problems during the swing phase of walking. They concluded that while the Riordan transfer technique using a tendon-to-tendon anastomosis works well in patients with low demands, it may stretch out to failure in patients with high demands.\textsuperscript{19} Using a tendon-to-bone attachment for the tibialis posterior tendon in our technique has shown no loss of function over time, but our follow-up was shorter.

In a study by Yeap et al, which reported on 12 patients with either traumatic common peroneal or sciatic nerve injury, 11 of 12 patients had grade 4 or 5 dorsiflexion, but the torque generated by the transferred tendon was only about 30% of the normal contralateral side. We found that our patients had 18% of torque in dorsiflexion at 60 degrees per second. While data were not presented on return to activity in this current study, Yeap et al noted in their discussion that 1 patient did compete in a triathlon.\textsuperscript{27,28}

Decreased plantarflexion ankle ROM and plantarflexion strength were noted in the Bridle participants as compared with controls, and this has been noted in kinematic studies following the Bridle procedure as well as the total split posterior tibial tendon transfer.\textsuperscript{3,7} It is unknown whether these findings are related to a tethering effect of the posterior tibialis muscle, which has a shorter excursion than the anterior tibialis; weakness of the gastrocnemius-soleus complex following operative lengthening; plantarflexor muscle weakness secondary to an occult tibial nerve injury that occurred at the time of the peroneal nerve injury or cast and brace immobilization; or a combination of these causes. Given these findings, we emphasize protected ROM at 6 weeks and early calf muscle strengthening postoperatively. If the patient cannot preoperatively achieve at least 5 degrees of ankle joint dorsiflexion with the knee in extension, we encourage preoperative aggressive calf muscle–stretching exercises in hopes of avoiding gastrocnemius-soleus muscle lengthening.

Our study is not without limitations. It is retrospective in nature, and although many participants had preoperative data that were useful in evaluating the impact of this operation, not all participants had preoperative data for comparison. Additionally, we were able to evaluate only 19 of the 30 participants who met the inclusion criteria. Our study
group was also relatively heterogeneous, with multiple sites of nerve injury, different mechanisms of injury, and a wide age range. Despite these limitations, we present a detailed description of the Bridle technique and a thorough postoperative evaluation of a group of participants with a difficult problem. Postoperative evaluation was standardized in all regards, and the Bridle procedure was performed by 2 surgeons at 1 site in identical fashion with a standardized postoperative treatment and rehabilitation protocol.

**Conclusion**

In conclusion, the Bridle procedure resulted in 100% satisfaction (12 excellent and 7 good) and provided a significant improvement in the ADL and sports subsections of the FAAM without negatively affecting foot alignment measures. Despite deficits in ROM, strength, and validated outcome measures when compared with controls, the Bridle procedure resulted in a high level of function in patients with foot drop as a result of peroneal nerve injury. Postoperatively, no participant required an AFO for walking.

**Declaration of Conflicting Interests**

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Arthrex Bio-Tenodesis screws were utilized for the Bridle procedure. Jeffrey E. Johnson, MD, is a paid speaker for Arthrex and the Midwest Stone Institute, which receives a fellowship funding grant from Arthrex and the Midwest Stone Institute to defray the cost of the fellowship training. Jeremy J. McCormick, MD, has been sponsored to attend an Arthrex laboratory.

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