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Simultaneous Anterior Tibial Tendon Repositioning and Partial Posteromedial Soft Tissue Surgery for Recurring Clubfoot Deformity in Children between Three and Six Years of Age: A Review

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Abstract

Background: Congenital talipes equinovarus (CTEV) is among the most prevalent structural birth defects, affecting approximately 1 per 1000 live births and carrying significant long-term functional consequences when inadequately managed. Despite high initial correction rates with the Ponseti method, relapse occurs in 5–55% of treated cases, most commonly manifesting as dynamic foot supination during the swing phase of gait in children aged 2.5 to 5 years. Combined tibialis anterior tendon transfer (TATT) with limited posteromedial release (PMR) has emerged as the surgical approach of choice for this specific relapse pattern, offering comprehensive correction of both dynamic and static deformity components with low complication rates. This review examines the anatomy, biomechanics, pathological basis, surgical technique, and clinical outcomes of this combined procedure in the 3–6 year age group.

Keywords: congenital talipes equinovarus; clubfoot relapse; tibialis anterior tendon transfer; posteromedial release; dynamic supination; Ponseti method; pediatric orthopedics

Introduction

Clubfoot, formally designated congenital talipes equinovarus (CTEV), is one of the most frequently encountered structural birth defects in pediatric orthopedic practice, with a global prevalence averaging approximately 1 per 1000 live births and considerable geographic variation ranging from 0.39 per 1000 in Chinese populations to as high as 7 per 1000 among native Hawaiian and Maori communities. (1)

The condition involves a complex three-dimensional deformity of the foot and ankle characterized by the acronym CAVE: cavus, adduction, varus, and equinus, each component arising from distinct anatomical and biomechanical disruptions, and in the majority of cases it is idiopathic, occurring as an isolated finding without associated syndromic or neuromuscular pathology, though syndromic forms constitute approximately 20% of all presentations. (2)

The Ponseti method has become the globally accepted standard of care for primary CTEV, achieving correction rates exceeding 80–90% through serial manipulation, casting, and prolonged foot abduction orthosis use, yet relapse remains a substantial clinical challenge occurring in 5–55% of patients and constituting the most common reason for surgical intervention in the preschool age group. (3)

Dynamic supination during the swing phase of gait, driven by overactivity of the tibialis anterior muscle against a background of weak peroneal musculature, accounts for approximately 68% of relapse presentations and defines the clinical scenario in which combined TATT with limited PMR is most clearly indicated. (4)

Normal Anatomy of the Foot and the Tibialis Anterior

The human foot comprises 26 bones organized into the hindfoot, midfoot, and forefoot, with major articulations including the tibiotalar joint permitting dorsiflexion and plantarflexion, the subtalar joint mediating inversion and eversion, and the midtarsal and tarsometatarsal joints contributing to forefoot flexibility and stability, while three interdependent arches — medial longitudinal, lateral longitudinal, and transverse — distribute mechanical load during stance and locomotion with their integrity depending on coordinated ligamentous tension and dynamic muscle activity. (6)

The tibialis anterior muscle originates from the lateral condyle and proximal two-thirds of the lateral tibial surface, the interosseous membrane, and the deep fascia of the leg, with its tendon inserting onto the medial cuneiform and the base of the first metatarsal, making it the principal dorsiflexor of the ankle and a key dynamic stabilizer of the medial longitudinal arch, innervated by the deep fibular nerve at spinal levels L4, L5, and S1, and receiving its blood supply from the anterior tibial artery. (7)

During the gait cycle, the tibialis anterior contracts eccentrically during the loading response to control plantarflexion and absorb shock at heel strike, remains relatively quiescent during mid-stance while the gastrocnemius-soleus complex dominates, and then contracts concentrically throughout the swing phase to dorsiflex the ankle and ensure toe clearance, with this swing-phase activity being of particular relevance to clubfoot relapse because the medial insertion of the tendon simultaneously produces inversion alongside dorsiflexion, and when peroneal muscles are weak this unopposed inversion generates dynamic supination. (8)

Pathological Anatomy and Biomechanics of Clubfoot

The deformity in CTEV arises from abnormalities spanning bone morphology, joint alignment, soft tissue architecture, and muscle-tendon dynamics, with the talus serving as the central pathological structure whose neck is medially angulated and plantarflexed, displacing the navicular and entire forefoot medially and plantarward, while the calcaneus is tilted and rotated medially beneath the talus contributing to both varus and equinus components, and the forefoot is adducted and supinated producing the characteristic CAVE deformity that defines the condition at birth. (9)

These skeletal distortions are inseparable from the surrounding soft tissue pathology, as the Achilles tendon is shortened and contracted, medial and posterior joint capsules are thickened and fibrotic, and the deltoid ligament complex is abnormally tight, collectively reinforcing the fixed deformity and resisting correction through purely mechanical means. (10)

From a biomechanical standpoint, the muscle imbalance between the tibialis anterior and the peroneal muscles disrupts normal foot mechanics by driving dynamic supination during ambulation, and Dimeglio's classification system grades the deformity from I to IV based on the reducibility of equinus, varus, rotation, and adduction, with higher grades predicting greater resistance to conservative correction and higher relapse risk, while the Pirani scoring system offers a complementary clinical tool grading six specific signs to quantify deformity severity and monitor the progress of correction over time. (11)

Etiology, Epidemiology, and Classification of Relapse

Relapse following initially successful Ponseti treatment is multifactorial in etiology, with non-compliance with the foot abduction brace remaining the single most common cause since the brace must be worn nightly until the age of 4–5 years to maintain correction during the period of rapid foot growth, while muscle imbalance specifically involving tibialis anterior overactivity against peroneal weakness drives dynamic supination, incomplete initial correction leaves residual equinus predisposing to recurrence, and children with syndromic or neuromuscular conditions such as spina bifida or arthrogryposis have substantially higher relapse rates requiring more extensive intervention. (12)

Relapses are clinically classified as early (before walking age), late (in children aged 2–5 years), and rigid, with early relapse manifesting as return of adductus or varus and loss of dorsiflexion generally manageable with Ponseti re-casting, late relapse characterized by dynamic supination during gait being the primary indication for TATT, and rigid relapse involving stiff equinus and midfoot contracture typically requiring casting followed by surgical correction. (13)

The distinction between dynamic and static relapse is fundamental to surgical planning, as in dynamic relapse the foot appears normal at rest but supinates visibly during the swing phase of walking indicating a functional deformity driven by muscle imbalance, whereas in static relapse the deformity persists at rest and during all phases of movement reflecting fixed soft tissue contractures or bony abnormalities that require a different therapeutic approach. (14)

Diagnosis and Clinical Assessment of Relapsed Clubfoot

The diagnosis of relapsed CTEV is primarily clinical, anchored in a structured history documenting the age at initial treatment, the method used, compliance with the foot abduction brace, and any prior surgical interventions, since these details substantially influence both the likelihood of relapse and the appropriate management strategy, followed by careful physical examination beginning with observation during walking where dynamic supination is visible only during the swing phase and may be entirely absent at rest. (15)

Palpation and range of motion assessment focus on ankle dorsiflexion, which should ideally reach at least 10–15° for surgical candidacy since dorsiflexion below 10° indicates early relapse or residual equinus that must be addressed before tendon transfer, while muscle balance assessment identifies the specific tibialis anterior overactivity and peroneal weakness characterizing dynamic relapse and guiding the decision for tendon transfer. (16)

Radiological evaluation using weight-bearing anteroposterior and lateral foot radiographs assesses the talocalcaneal angle, talo-first metatarsal angle, and calcaneal height, with confirmation of the lateral cuneiform ossific nucleus being an essential preoperative step since it serves as the bony insertion point for the transferred tendon and is typically present by 2.5 years of age, while the Dimeglio score and Garceau and Palmer criteria provide validated numerical and functional measures for rating deformity severity and surgical outcomes respectively. (17)

Treatment of Relapsed Clubfoot

Conservative Options

The management of relapsed CTEV follows a stepwise approach with conservative measures preceding surgical intervention in most cases, with Ponseti re-casting serving as the first-line treatment employing the same principles of weekly manipulation and long-leg casting used for primary correction, typically requiring two to six casts to restore forefoot abduction, correct varus and cavus, and regain adequate dorsiflexion. (18)

Repeat percutaneous Achilles tenotomy or Z-plasty lengthening is indicated when dorsiflexion cannot be restored beyond 10° with casting alone and is an essential prerequisite for any subsequent tendon transfer procedure, as residual equinus after TATT dramatically increases the risk of failure, and re-institution of the foot abduction brace protocol is mandatory following any conservative or surgical treatment of relapse since the evidence consistently demonstrates that non-compliance is the primary driver of recurrence. (19)

For rigid relapses failing conservative management, operative options including posteromedial soft tissue release, plantar fascia release, midfoot osteotomies, and lateral column lengthening are available but are generally reserved for older children with structural deformity and should not be applied to flexible dynamic relapses where tendon transfer alone is sufficient, while in adolescents and skeletally mature patients with severe rigid deformity and arthritic change, osteotomies or arthrodesis may ultimately be required as salvage procedures. (20)

Tibialis Anterior Tendon Transfer

The pathophysiological rationale for TATT is that in idiopathic CTEV the tibialis anterior muscle retains near-normal strength while the peroneal muscles are weak and unable to counterbalance its inversion force, so transferring the entire tendon to the lateral cuneiform repositions its mechanical line of action to the midline of the foot converting it from a dorsiflexor-inverter into a pure dorsiflexor, thereby eliminating the supination force and restoring muscle balance, with full rather than split transfer consistently recommended since partial transfer preserves the medial insertion vector reduces the corrective force and the already-weakened muscle cannot afford the further loss of power that split transfer entails. (21)

The optimal age for TATT is 2.5–4 years, as the ossific nucleus of the lateral cuneiform is sufficiently developed for secure tendon fixation and the foot retains adequate biological responsiveness to muscle rebalancing, with the foot needing to be fully corrected and flexible before transfer is undertaken so that any residual rigid equinus or varus is addressed with casting and if necessary Achilles lengthening prior to surgery. (22)

The standard operative technique begins with a medial dorsal incision over the tibialis anterior insertion where the tendon is carefully dissected using sharp release from proximal to distal while avoiding injury to adjacent periosteum and cartilage, then prepared with a Bunnell-type stitch using strong non-absorbable suture secured over its distal 2–3 cm, after which fluoroscopy identifies the lateral cuneiform through a 2 cm dorsolateral incision and a drill hole is made centrally through the bone toward the plantar surface directed to avoid plantar neurovascular structures, before the tendon is passed subcutaneously via a blunt hemostat tunnel, threaded through the osseous tunnel, and tensioned with the foot in maximum abduction and moderate dorsiflexion before being secured with a plantar button and non-absorbable suture. (23)

Limited Posteromedial Release

While TATT addresses the dynamic component of relapse by restoring muscle balance, limited posteromedial release targets residual static deformity arising from soft tissue contractures that cannot be corrected by casting alone, and is specifically a selective targeted release of the structures perpetuating deformity rather than a full circumferential subtalar release, thereby reducing the risk of overcorrection, avascular necrosis, and loss of joint motion associated with more extensive surgical approaches. (24)

Through the medial approach used for tendon harvest, the talonavicular, navicular-medial cuneiform, and medial cuneiform-first metatarsal joint capsules are identified and their medial and inferior aspects released, the abductor hallucis tendon is released at its insertion and the plantar fascia divided, the tibialis posterior tendon and flexor digitorum muscles are released as needed, posterior and medial releases are performed in the subtalar region, and if dorsiflexion remains below 20° Z-plasty lengthening of the Achilles tendon is performed with posterior capsulotomy added if necessary thereafter. (25)

The combination of limited PMR with TATT offers comprehensive single-stage correction of both dynamic and static deformity components, with the indication for combined rather than isolated TATT being a foot demonstrating dynamic supination alongside mild to moderate static deformity that preoperative casting has not fully resolved, while contraindications include bean-shaped feet with long lateral cavus requiring double osteotomy, severe rigid deformity, and neuromuscular or syndromic etiology, and the postoperative protocol involves an above-knee cast for four weeks with non-weight bearing followed by a below-knee cast for two further weeks with partial weight bearing before full resumption of normal activity without bracing. (26)

Clinical Outcomes and Comparative Evidence

The clinical evidence supporting combined TATT with limited PMR in relapsed CTEV is largely favorable, with Abdelrahman et al. reporting good to excellent outcomes in over 90% of cases using Garceau and Palmer criteria with significant postoperative improvement and high family satisfaction, while Holt et al. demonstrated durable correction and maintained gait function over a 37–55 year follow-up period following TATT for relapsed idiopathic clubfoot, providing the strongest available evidence for the longevity of the procedure. (27)

Agarwal et al. compared three different TATT fixation methods and found that full transfer to the lateral cuneiform consistently outperformed split and partial transfer techniques confirming the biomechanical logic of complete muscle rebalancing, while Yalcın et al. reported satisfactory clinical and radiological correction with low complication rates following PMR for relapsed clubfoot supporting its use when conservative methods fail, and Lampasi et al. noted that while combined tendon transfer with more extensive soft tissue release achieved meaningful functional score improvements, complication rates including failure of transfer and overcorrection were notable reinforcing the principle that surgical extent should match the specific deformity pattern. (28)

Complications of combined TATT with limited PMR are uncommon when patient selection criteria are respected, with superficial wound infection occurring in fewer than 10% of cases in most series and manageable with antibiotics without impact on the final surgical result, while overcorrection producing calcaneovalgus is a recognized risk particularly when the transferred tendon is overtensioned, and recurrence of dynamic supination after TATT is more likely when the procedure is performed before full foot correction, when residual rigid equinus persists, or when split rather than complete transfer is performed, although long-term follow-up studies have not identified significant late functional deficits attributable to loss of the medial cuneiform insertion. (29)

Special Considerations

Age, Timing, and Patient Selection

Patient selection for combined TATT with limited PMR requires careful clinical and radiological assessment targeting children aged 3–6 years with idiopathic CTEV initially managed with the Ponseti method who present with dynamic supination during the swing phase, a flexible or semi-flexible foot passively correctable to neutral, adequate ankle dorsiflexion of at least 10–15° after preoperative casting, and a confirmed ossific nucleus of the lateral cuneiform on radiograph, with children below age 3 generally managed by repeat casting since the lateral cuneiform may not yet be adequately ossified, and children above age 6 with significant residual deformity potentially requiring additional bony procedures as the biological window for pure soft tissue correction narrows with advancing skeletal maturation. (30)

The positive correlation between older age at surgery and higher postoperative Dimeglio scores indicating slightly less complete correction in older children within the 3–6 year range has been documented across multiple studies and reinforces the clinical principle of intervening as soon as the indication is clearly established rather than adopting a prolonged wait-and-see approach, with preoperative serial casting to maximize foot flexibility being an essential preparatory step since any residual equinus must be resolved before transfer to avoid excessive tendon tension and risk of fixation failure or deformity recurrence. (31)

In syndromic or neuromuscular cases the biological and mechanical environment differs substantially from idiopathic CTEV with stiffer tissues, greater relapse rates, and reduced responsiveness to muscle rebalancing, meaning these cases are managed with more extensive procedures tailored to the underlying condition and fall outside the standard indications for combined TATT with limited PMR, while the broader management principle that parental education and brace compliance remain the most powerful tools for preventing relapse in the first instance applies across all etiological groups and must be addressed in every clinical encounter. (32)

Conclusion

Combined tibialis anterior tendon transfer with limited posteromedial release is a safe, effective, and durable surgical option for the management of relapsed congenital talipes equinovarus in children aged 3 to 6 years, offering comprehensive correction of both dynamic and residual static deformity components with high rates of good to excellent functional outcomes, low complication rates, and no clinically significant long-term sequelae when performed in appropriately selected patients following full preoperative foot correction, with younger age at surgery consistently associated with better postoperative results reinforcing the value of timely intervention within this defined therapeutic window. (32)

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