Advanced International Journal for Research (AIJFR)

E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

A Literature Review of Tibial Cortex Transverse Transport in Ischemic Limb Salvage

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Abstract

Tibial Cortex Transverse Transport (TTT) is an emerging surgical technique used in the treatment of ischemic foot pathologies, especially in patients with diabetic foot ulcers (DFUs), peripheral artery disease (PAD), and chronic limb-threatening ischemia (CLI). Based upon the Ilizarov's tension-stress principle, the TTT technique implements a tibial corticotomy followed by a controlled mechanical distraction of the segment with the goal of promoting both localized and systemic angiogenesis.

This review collects research from peer-reviewed literature published between January 2020 and July 2025, assessing the clinical efficacy, immunological findings, and the revascularization potential of TTT in limb salvage.

Clinical studies consistently demonstrate that TTT enhances wound healing by promoting neovascularization. It was also found that distal perfusion improved in patients when other methods of healing were unsuccessful. Angiographic evidence reveals strong evidence of the formation of new vascular networks. In addition, increasing the Ankle-Brachial Index and observable warming of ischemic limbs were noted, showing improvements in microcirculation. Furthermore, TTT was shown to activate mechanisms responsible for regeneration, with those immunological markers being present during wound healing.

While promising results have been expressed through clinical success and high rates of limb salvage, limitations still remain. Challenges such as potential complications, lack of procedural consistency, cytokine response variability, and a low volume of randomized controlled trials suggest the need for more research. Nonetheless, TTT is an alternative therapeutic method for patients with poor revascularization and limited treatment options, displaying a growing body of research supporting its function as a regenerative limb salvage intervention.

1. Introduction:

In the world of podiatry, there are a variety of conditions patients will present with. Pathology commonly includes vascular complications, which tend to impair proper blood flow to the lower extremity. These complications commonly are associated with conditions such as diabetes mellitus, peripheral artery disease (PAD), and chronic limb ischemia (CLI). In patients with poor revascularization, managing ischemic foot pathology creates a serious challenge.

Tibial Cortex Transverse Transport (TTT), a fairly new surgical technique, has emerged as a possible treatment option. TTT is a surgical method based on the Ilizarov technique being used in patients with diabetic foot ulcers (DFU), PAD, and/or CLI. The procedure includes a corticotomy in the anteromedial tibia at the mid-diaphyseal level, followed by gradually transporting the bone segment transversely for a period, then moving the bone back to its original position to promote angiogenesis. This solution would seem to be advantageous in patients who have poor revascularization, promoting angiogenesis and improving tissue perfusion in ischemic limbs. There have been a multitude of studies performed to test the success of this new procedure, and this review article will discuss the findings of the TTT procedure to discover its efficacy in vascular pathology patients, assessing its potential role in limb salvage.

Methods:

A comprehensive literature search was performed using published articles from established journal databases such as PubMed, Sciencedirect, and others. The date for criteria was set between January 2020 to July 2025. Keywords from the search included the following: Tibial Cortex Transverse Transport (TTT), diabetes mellitus, diabetic foot ulcer (DFU), peripheral artery disease (PAD), chronic limb ischemia (CLI), angiogenesis, and revascularization.

The articles were screened by the two authors of this review article. Inclusion criteria included published peer-reviewed research articles, human studies, animal studies, studies of TTT with any keywords used, and outcomes discussing the efficacy of TTT. Exclusion criteria was limited to non-English research, and no-published research.

Results:

The use of Tibial Cortex Transverse Transport (TTT) in patients with chronic limb ischemia, diabetic foot ulcers (DFUs), peripheral artery disease (PAD), and non-healing soft tissue defects has consistently produced positive results in terms of wound healing, neovascularization, and limb preservation. Across a number of varied populations and healthcare systems, TTT has shown clinical viability as a limb salvage procedure, particularly for patients unresponsive to conventional interventions (Chen et al., 2019; Nie et al., 2021; Orthofix Medical Inc., 2024).

When it comes to clinical healing outcomes, multiple studies show that TTT significantly accelerates wound healing time in patients with ischemic ulcers and recalcitrant soft tissue injuries. In a U.S. cohort of six patients with advanced stage foot ulcers and evidence of gangrene, all were able to complete epithelialization within 12 weeks following surgery. Notably, the majority of these patients had prior unsuccessful revascularization procedures or amputations, indicating the potential of TTT as a strong and effective intervention (Orthofix Medical Inc., 2024). Similarly, reports from China and Germany have shown limb salvage success rates over 90%, with wound closure achieved within 6-10 weeks. These outcomes were observed even in patients with non-diabetic ulcers and hypovascular non-unions, increasing hope for the potential of the technique as a therapeutic option (Chen et al., 2019).

The staple of the TTT approach is its ability to induce distraction-mediated neovascularization, or angiogenesis, a process which relies on controlled mechanical stress applied to living tissue (Zhao et al., 2021). Angiographs and other clinical imaging methods consistently show the formation of new vascular networks in areas distal to the corticotomy site, most notably in the foot and ankle region. These newly formed vessels often orient “parallel to the vector of distraction”, providing direct evidence of targeted angiogenesis (Nie et al., 2021; Orthofix Medical Inc., 2024). Patients also have shown improvements in distal perfusion, proven with increases in Ankle-Brachial Index (ABI) scores and increased skin temperatures. Reports describe observable warming of ischemic limbs and reduction of pain within 24–72 hours after the corticotomy procedure is concluded. This is likely due to decreased intramedullary pressure and early microcirculatory enhancement (Orthofix Medical Inc., 2024; Chen et al., 2019).

Outside of perfusion, TTT has demonstrated systemic regenerative effects. Studies suggest that the mechanical stimulation of bone and soft tissue propagates mesenchymal stem cells and immunomodulatory factors, enabling a broader range for tissue repair (Zhao et al., 2021; Orthofix Medical Inc., 2024). Experiments also display the congregation of macrophages and endothelial progenitor cells, which assists in wound remodeling and the resolution of chronic inflammation (Yu et al., 2025; Liu et al., 2024). The use of modern surgical guides and transport systems, such as the TrueLok™, has improved procedural accuracy and reproducibility (Orthofix Medical Inc., 2024). However, the core biological response is driven by the Ilizarov tension-stress principle (developed by Gavriil Abramovich Ilizarov), not the hardware itself, which solely acts as a guide for the surgeon. While dedicated instrumentation can support corticotomy alignment accuracy and distraction timing, the driving factor for clinical benefit remains the biomechanical incorporation of tissue regeneration.

Discussion:

Tibial Cortex Transverse Transport (TTT) has emerged as a promising surgical strategy in the management of chronic limb ischemia (CLI), diabetic foot ulcers (DFU), and peripheral artery disease (PAD), as well as other pathologies defined by microvascular insufficiency and poor wound healing. The main principle underlying TTT is Ilizarov’s "tension-stress effect," which includes gradual mechanical distraction of living tissue, stimulating cellular proliferation, neovascularization, and tissue regeneration. This concept is known as distraction histogenesis. It provides the biological rationale for using TTT as a regenerative technique rather than simply a structural intervention.

Recent research has demonstrated that tibial transverse transport (TTT) not only promotes localized angiogenesis, but may also stimulate bilateral neovascularization, even when applied unilaterally. In a diabetic rabbit foot ulcer model, both unilateral and bilateral TTT significantly accelerated wound healing compared to control patients, with bilateral TTT achieving faster and more complete healing (Wang et al., 2024). Histological analysis in the experiment revealed enhanced collagen deposition and an increase in density of smaller vessel walls in the TTT-treated groups. A higher expression of vascular endothelial growth factor receptor 2 (VEGFR2) and Tie-2 positive endothelial progenitor cells suggests a systemic angiogenic response, supporting the concept that unilateral TTT can stimulate neovascularization beyond the treated limb. These findings demonstrate the therapeutic potential of TTT in managing chronic wounds by mobilizing endothelial progenitor cells, thus promoting angiogenesis, which could possibly be done through various systemic signaling pathways (Wang et al., 2024).

The mechanobiological effects of TTT extend beyond the tibial corticotomy site. The distraction segment reduces intramedullary pressure, enhances microcirculation, and induces both local and systemic release of growth factors and cytokines. Studies in both animal subjects and human patients have shown a continuous upregulation of vascular endothelial growth factor (VEGF) and CD31 expression, which are markers for neovascularization. Additionally, research published by Oxford Academy presented significant increases in capillary density and granulation tissue formation following TTT, supporting its efficacy as a regenerative tool in ischemic wounds. These vascular improvements are not purely radiological. Patients treated with TTT exhibited faster wound healing, improved Ankle-Brachial Indices, and reduced recurrence of ulceration.

The immunological effects of TTT are just as significant. An increasing amount of evidence supports the view that TTT not only assists and stimulates angiogenesis, but also regulates the immune environment. A study in the International Journal of Surgery showed that TTT induces a shift in macrophage polarization from the pro-inflammatory M1 phenotype to the reparative M2 type, while also increasing the circulation of bone marrow-derived stem cells. This immune reprogramming can be critical in diabetic patients, where chronic inflammation suppresses healing. Further support comes from Frontiers in Endocrinology, which reported significant reductions in systemic markers of inflammation, such as IL-6 and CRP after TTT. Critically, this was present even in the absence of adjunctive revascularization procedures.

These findings are demonstrated by a procedural video published by Double Medical Technology Inc., which shows a step-by-step visual of the surgical technique. This video emphasizes several key technical points such as, ensuring proper fluoroscopic alignment of the osteotomy, achieving precise unicortical pin placement, and monitoring segment transport throughout the distraction and consolidation phases. These surgical steps are vital, as they minimize the risk of hardware instability, segment impingement, and incomplete corticotomy, all of which can compromise clinical outcomes. The ability to visualize and reproduce these technical details demonstrated in the video is of utmost importance for a more widespread use of the technique in both academic and community settings.

In an interview with Dr. Gabriel Mitchell DPM, we discussed the vertical location of the TTT on the tibia. He stated how the vertical location of the TTT can vary, "producing an equal amount of angiogenesis, regardless of the location of the tibial corticotomy (Mitchell, personal communication, July 26, 2025)." He also mentioned how "approximately 75% of patients who undergo a major limb amputation experience significant cardiac-related issues." This allows the TTT procedure to be considered as an adequate alternative to amputation in terminal patients, decreasing the likelihood of cardiac pathologies in post-operative patients. Dr. Mitchell states that he has performed this procedure 4 times, on a wide variety of patients, and hopes to continue the use of TTT clinically, while continuing his own research with optimistic results.

Clinically, TTT is an especially valuable option in patients who are poor candidates for conventional revascularization, such as those with no distal runoff, failed prior grafts, or extensive soft tissue infection. The procedure also has the potential to act as an alternative to amputation in eligible patients. U.S. based and international case series have shown remarkable outcomes, especially in diabetics. Patients with severe, non-healing DFUs were able to achieve complete wound closure within 12 to 16 weeks post-operatively, alongside improvements in perfusion and functional mobility.

Nonetheless, certain limitations and challenges remain. As noted in FASTRAC Journal, variability in cytokine response and individual immune profiles may influence outcomes, with some cases reporting excessive fibrosis or localized infection associated with the hardware. These complications focus on the importance of patient selection, surgical precision, and post-operative follow-up. Moreover, while preclinical and early clinical studies are encouraging, the field lacks larger experimental groups and randomized trials, which are needed to confirm long-term durability, patient-reported outcomes, and cost-effectiveness when compared to traditional interventions.

Conclusion:

The Tibial Cortex Transverse Transport (TTT) procedure is a promising development in the treatment of lower extremity vascular pathologies, especially in patients with diabetic foot ulcers (DFU), critical limb ischemia (CLI), or peripheral artery disease (PAD). Current evidence discussing TTT shows that it can promote angiogenesis, improve microcirculation, and support limb salvage patients' well being, while displaying overall low complication rates.

However, research studies remain limited, with some articles having either a small sample size, low clinical experiences, or specific patient based results. Nonetheless, even with early outcomes being encouraging, they should be interpreted with some caution.

To enhance results on the efficacy and safety of TTT, continued high quality studies with more clinical trials are needed, which seem to be increasing with time. Overall, this promising procedure is growing in usage by volume with strong signs of patient success.

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