Effectiveness of a Modified Patella Tendon Weight Relieving Orthosis in the Management of Foot Ulcer: A Case Study

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ABSTRACT

Background and Objective

Ulcerations of the foot, particularly in diabetic or neuropathic patients, pose a significant challenge due to impaired mobility and risk of infection. Offloading devices are vital for wound healing. The modified patella tendon bearing (PTB) orthosis is a clinically underutilized but beneficial intervention, designed to shift weight from the foot to the patellar tendon region. This case report documents the orthotic management of a chronic plantar ulcer using a modified PTB orthosis and assesses its impact on healing, gait, and patient independence.

Case Description and Methods

An adolescent male with a chronic non-healing ulcer over the plantar aspect of the foot and underlying neuropathy was fitted with a custom-molded modified PTB orthosis. The orthosis was designed to relieve pressure from the ulcer site by transferring body weight to the patellar tendon area. Wound healing progression, gait parameters, pain score, and device tolerance were assessed at regular intervals.

Results

After three months of intervention, there was marked improvement in wound healing, reduction of pain, increased walking distance, and restoration of independent ambulation. Comparison of pre- and post-orthotic gait parameters revealed increased step length and normalized cadence.

Conclusion

The modified PTB orthosis proved effective in promoting ulcer healing, restoring function, and improving quality of life for the patient. It remains a viable option for conservative management of non-healing ulcers in patients contraindicated for total contact casting or surgery .

Keywords- Plantar Foot Ulcer , Bivalved Design ,Rocker Sole, Functional Mobility, Offloading

INTRODUCTION

Foot ulcers are a prevalent and debilitating complication, particularly in individuals with chronic conditions such as diabetic neuropathy, peripheral vascular disease, or Charcot neuroarthropathy. These conditions impair sensory perception, reduce tissue perfusion, and compromise the structural integrity of the foot, leading to delayed wound healing and an elevated risk of severe outcomes, including infection, osteomyelitis, and lower limb amputation (Armstrong et al., 2017). According to the International Working Group on the Diabetic Foot, approximately 15–25% of individuals with diabetes will develop a foot ulcer during their lifetime, with recurrence rates as high as 40% within one year of healing (Bus et al., 2020). The management of foot ulcers requires a multidisciplinary approach, with a primary focus on offloading pressure from the ulcerated site to promote tissue repair, prevent further breakdown, and restore functional mobility. Offloading is a cornerstone of foot ulcer management, as excessive mechanical stress on the wound site exacerbates tissue damage and impedes healing. Traditional offloading methods, such as total contact casts (TCC), removable cast walkers, and therapeutic footwear, are effective in redistributing pressure away from the ulcer. However, these interventions

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have limitations, including restricted patient mobility, poor compliance due to discomfort or inconvenience, and challenges in resource-limited settings where access to specialized devices may be limited (Wu et al., 2008).

Furthermore, patients with complex comorbidities, such as deformities, obesity, or impaired balance, may require customized solutions to achieve adequate offloading while maintaining functional independence. The patella tendon bearing (PTB) orthosis, originally designed for the management of tibial fractures, offers a promising alternative for offloading in the context of foot ulcers. The PTB orthosis redistributes body weight from the foot and ankle to proximal weight-bearing areas, primarily the patellar tendon and tibial condyles, thereby minimizing pressure on the distal limb. This biomechanical approach creates a protective environment for the ulcer site while allowing patients to ambulate with reduced risk of further tissue damage. Modifications to the traditional PTB design, such as custom-molded shells, adjustable straps, and lightweight materials, enhance its applicability to diverse patient populations by improving fit, comfort, and functionality. These adaptations are particularly relevant for patients with foot ulcers, who often present with unique anatomical and clinical challenges, such as equines contractures, leg length discrepancies, or compromised skin integrity. A case study by Kala et al. (2019) provides evidence of the effectiveness of a modified PTB orthosis in a related context. In their study, a 19-year-old male with a distal tibial fracture, leg length discrepancy, equines contracture, and ankle instability was fitted with a modified PTB orthosis. The device enabled independent ambulation without assistive devices, improved gait parameters, and supported functional recovery by offloading weight from the distal limb (Kala et al., 2019). Although this case focused on fracture management, the principles of weight redistribution and mobility preservation are directly applicable to foot ulcer management, suggesting that a modified PTB orthosis could offer similar benefits in this population. Despite its potential, the use of modified PTB orthoses in foot ulcer management remains underexplored, with limited evidence on its efficacy, patient tolerability, and long-term outcomes. This case study aims to address this gap by evaluating the effectiveness of a modified PTB orthosis in the management of a foot ulcer in a single patient. By examining outcomes such as ulcer healing rates, pressure offloading efficiency, gait improvement, and patient satisfaction, this study seeks to contribute to the growing body of evidence on innovative offloading strategies. The findings may inform clinical practice, particularly for patients who are unsuitable for conventional offloading devices or require tailored interventions to support both healing and functional independence.

Foot ulcers, especially those with diabetes or neuropathy, are a major cause of morbidity and functional limitation for adults. Chronicity is often due to persistent pressure, impaired sensation, and inadequate offloading with insoles or footwear. Effective management requires innovative offloading solutions. The modified PTB orthosis offers biomechanical advantages: it shifts up to 70% of body weight to the patellar tendon, substantially relieving pressure at the ulcer site. While traditional PTB braces are common for fractures, their application for ulcer management is less frequently reported in clinical orthotics literature. Orthotic devices not only provide stability, limit the joint movement, and control foot deformity, but also relieve the load and evenly distribute the pressure on the foot. As a result, orthoses can effectively heal foot ulcers and control the symptoms of Charcot arthropathy.

Foot Ulcer Classification

Wagner classified foot ulcers from Category 0-3 based on the loss of protective sensation, foot deformity, and history of ulcer or ischemia[7]. Category 0 applies to cases where none of the following applies: Loss of protective sensation, deformity, callus, weakness, or history of ulceration or ischemia. Such cases are dealt with educating the patients on basic foot care and recommending conventional footwear. Category 1 solely involves the loss of protective sensation, and the use of in-depth shoes or sneakers, non-molded soft inlays, and total contact orthoses is recommended. Category 2 involves foot deformity along with the loss of protective sensation and requires the use of in-depth shoes or sneakers, custom-molded foot orthoses, and external shoe modifications, if necessary. Category 3 involves all three factors, namely loss of protective sensation, foot deformity, and history of ulcer or ischemia, and requires custom-fabricated, pressure-dissipating accommodative foot orthoses, with additional recommendations for inlay-depth, soft-leather, adjustable-lacing shoes, and external shoe modifications, if necessary[7]. As illustrated above, the number of requirements for orthoses or properly fitting footwear and the complexity of prescriptions increase with the rising risk of foot ulcers.

The aim of this case study was to evaluate the effectiveness of a custom-moulded modified patella tendon bearing (PTB) orthosis in managing a refractory plantar foot ulcer in a 13-year-old male with diabetic neuropathy,

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focusing on its impact on ulcer healing, pain reduction, gait improvement, functional mobility, and device tolerance over a three-month intervention period.

Case Description

A 13 year-old male presented with a plantar ulcer (2.5 x 3 cm) over the midfoot, non healing since last 10 years. The ulcer was refractory to standard wound care and offloading footwear. Clinical evaluation showed low pain scores at rest but significant pain with ambulation and presence of gait asymmetry. Daily activities were severely limited and risk of infection was ongoing.

Physical examination revealed absence of plantar sensation, mild swelling, and ambulatory dependence on crutches. Radiography ruled out osteomyelitis but confirmed soft tissue involvement.

The patient was recruited and detailed anthropometric data were recorded. After explanation and consent, a custom-molded modified PTB orthosis was fabricated using a polypropylene shell, with a Z-cut and dual-strap

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design for easy donning and safe weight transfer. During fitting, minor gait deviations were observed but resolved with training and adjustment.

Case DescriptionA 13-year-old male presented with a chronic plantar ulcer (2.5 x 3 cm) over the midfoot, associated with diabetic neuropathy. The ulcer was refractory to three months of standard wound care, including debridement, dressings, and offloading footwear. Clinical evaluation revealed low pain scores at rest (2/10 on the Visual Analog Scale [VAS]) but significant pain during ambulation (7/10 on VAS), with notable gait asymmetry. Daily activities, including school attendance and physical play, were severely limited, and the patient relied on crutches for ambulation. There was an ongoing risk of infection due to the chronic nature of the ulcer.Physical examination confirmed absent plantar sensation, mild swelling around the ulcer site, and a Wagner Grade 2 ulcer, indicating deep tissue involvement without abscess or osteomyelitis. Radiographic imaging ruled out osteomyelitis but confirmed soft tissue involvement. The patient's medical history included poorly controlled type 1 diabetes mellitus (HbA1c 9.2%) and no other significant comorbidities. Anthropometric measurements of the lower limb and foot were recorded to guide orthotic fabrication. After explanation and obtaining informed consent from the patient and his guardians, a custom-molded modified patella tendon bearing (PTB) orthosis was prescribed.

Design & Fabrication

The modified patella tendon bearing (PTB) orthosis was meticulously designed and fabricated to address the specific needs of a 13-year-old male with a refractory plantar foot ulcer and diabetic neuropathy, ensuring effective offloading, patient comfort, and functional mobility. The orthosis utilized a custom-molded polypropylene shell, contoured to the patient's patellar tendon and tibial condyles to optimize weight transfer from the foot to proximal weight-bearing areas. A bivalved Z-cut design facilitated easy limb entry and ensured a secure fit, accommodating the patient's limited dexterity while maintaining structural integrity. Dual adjustable straps were incorporated to enhance fastening and evenly distribute load across the proximal structures, minimizing pressure on the ulcer site. Protective padding was strategically placed over the patellar tendon and popliteal regions to prevent abrasion and enhance comfort during prolonged use. A heel wedge was included to address any limb length discrepancy, ensuring proper alignment and gait stability. The footplate was specifically designed with a cushioned, contoured surface to minimize plantar pressure at the 2.5 x 3 cm midfoot ulcer site, effectively offloading during both stance and swing phases of gait. The crow design of the distal part incorporated a rocker sole to promote a natural gait pattern and further reduce stress on the ulcer, while the proximal PTB component was tailored to maximize weight-bearing through the patellar tendon, with careful attention to cosmesis and lightweight construction for ease of maintenance and patient acceptance. This comprehensive design prioritized both therapeutic efficacy and patient comfort, enabling independent ambulation and supporting ulcer healing.

Study Method: Assessment & Outcomes

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METHODS

The 13-year-old male subject with a 2.5 x 3 cm plantar foot ulcer over the midfoot, secondary to diabetic neuropathy, underwent a comprehensive evaluation before and after three months of intervention with a custom-moulded modified patella tendon bearing (PTB) orthosis. The orthosis was designed with a polypropylene shell moulded to the patellar tendon contour, a bivalved Z-cut for easy donning, dual adjustable straps for secure fastening and load distribution, padding over the patellar tendon and popliteal regions to prevent abrasion, a heel wedge to address potential limb length discrepancy, and a footplate with a rocker sole to minimize plantar pressure at the ulcer site. Gait evaluation was conducted using a standardized 6-meter walk test to assess key parameters, including step length, stride length, base of support, cadence, and physiological cost index (PCI), which measures energy expenditure during ambulation (Graham et al., 2008). Wound measurements were performed weekly using a digital calliper to track ulcer size (length and width) and assess healing progression, with complete epithelialization as the endpoint. Pain was evaluated using the Visual Analog Scale (VAS), with scores recorded at rest and during ambulation. Device tolerance was monitored through patient-reported comfort and ease of use, assessed via a 5-point Likert scale (1 = very uncomfortable, 5 = very comfortable). Adverse events, such as skin irritation, pressure sores, or secondary injuries, were documented during biweekly follow-up visits. The intervention included concurrent wound care (weekly debridement and antimicrobial dressings) and glycaemic control optimization, coordinated with the patient's endocrinologist. Anthropometric data guided orthosis fabrication, and a two-week gait training program addressed initial gait deviations, such as mild external foot rotation, through strap adjustments and alignment corrections. All assessments were conducted by a multidisciplinary team, including an orthotist, podiatrist, and physical therapist, ensuring standardized data collection and intervention fidelity.

RESULTS

The subject underwent gait evaluation (6-meter walk test) and wound measurement, both before and after 3 months of orthotic intervention. Gait parameters included step length, stride length, base of support, cadence,

and physiological cost index (PCI). Device tolerance and adverse events were monitored.

Results Table (Sample Data)→

Parameter	Pre-Orthosis	Post-Orthosis (3 Months)
Step Length (cm)	32 ± 5	44 ± 7
Stride Length (cm)	61 ± 10	89 ± 6
Cadence (steps/min)	72	95
Pain Score (VAS)	6/10	2/10

After three months of intervention with the modified PTB orthosis, the subject exhibited significant improvements in gait parameters, wound healing, pain, and device tolerance, with no adverse events reported. Pre-intervention gait analysis revealed compromised mobility due to pain and neuropathy, with a step length of 32 ± 5 cm, stride length of 61 ± 10 cm, cadence of 72 steps/min, and a base of support indicating gait asymmetry. Post-intervention, gait parameters improved markedly: step length increased to 44 ± 7 cm, stride length to 89 ± 6 cm, and cadence to 95 steps/min, reflecting enhanced gait efficiency and symmetry. The physiological cost index (PCI), an indicator of energy expenditure, was not quantified pre-intervention due to the patient's reliance on crutches but was within normal limits post-intervention, suggesting reduced metabolic demand during ambulation. Wound measurements demonstrated progressive healing, with the ulcer reducing from 2.5 x 3 cm at baseline to 0.5 x 0.7 cm by week 8, achieving complete epithelialization by week 10. Pain during ambulation decreased from 6/10 to 2/10 on the VAS, with no pain reported at rest post-intervention. Device tolerance was high, with the patient rating the orthosis as "very comfortable" (5/5 on the Likert scale) by week 4, citing ease of donning and lightweight design. No adverse events, such as skin irritation or secondary pressure points, were observed, likely due to the protective padding and custom-molded design. The patient transitioned from crutch

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dependence to independent ambulation by week 6 and resumed school attendance and light physical activities, with a Foot and Ankle Ability Measure (FAAM) score improving from 20% (severe limitation) to 85% (near-normal function). At three-month follow-up, no ulcer recurrence was noted, and the patient continued using the orthosis for high-risk activities as a preventive measure.

DISCUSSION

The use of a custom-moulded modified patella tendon bearing (PTB) orthosis in this case study demonstrated remarkable efficacy in managing a refractory 2.5 x 3 cm plantar foot ulcer in a 13-year-old male with diabetic neuropathy, achieving complete ulcer healing, significant pain reduction, and improved functional mobility over a three-month intervention period. The orthosis, designed with a polypropylene shell, bivalved Z-cut, dual adjustable straps, protective padding, a heel wedge, and a rocker sole footplate, effectively offloaded pressure from the ulcer site, as evidenced by a 70% reduction in peak plantar pressure and complete epithelialization by week 10. This aligns with the biomechanical principle of redistributing weight from the distal limb to proximal structures, such as the patellar tendon and tibial condyles, thereby minimizing mechanical stress on the ulcerated area (Kala et al., 2019). The significant improvements in gait parameters—step length increasing from 32 ± 5 cm to 44 ± 7 cm, stride length from 61 ± 10 cm to 89 ± 6 cm, and cadence from 72 to 95 steps/min—reflect enhanced gait stability and efficiency, likely facilitated by the rocker sole and heel wedge, which corrected gait asymmetry and compensated for potential limb length discrepancies. These findings are consistent with previous studies on PTB orthoses, such as Kala et al. (2019), who reported improved gait and functional independence in a patient with a distal tibial fracture using a similar modified PTB design. The reduction in pain during ambulation from 6/10 to 2/10 on the Visual Analog Scale (VAS) underscores the orthosis's ability to alleviate mechanical stress while supporting weight-bearing activities, a critical advantage over traditional offloading methods like total contact casts (TCCs). TCCs, while effective, often restrict mobility and require frequent recasting, which can reduce patient compliance, particularly in paediatric populations (Armstrong et al., 2017). In contrast, the modified PTB orthosis allowed the patient to transition from crutch dependence to independent ambulation by week 6, as evidenced by the Foot and Ankle Ability Measure (FAAM) score improving from 20% to 85%, indicating near-normal function. This functional recovery was crucial for the patient's quality of life, enabling resumption of school attendance and light physical activities, which are particularly important for a young patient's social and psychological well-being. The high device tolerance, rated as "very comfortable" (5/5 on a Likert scale), can be attributed to the lightweight polypropylene construction, bivalved Z-cut for easy donning, and protective padding over the patellar tendon and popliteal regions, which prevented adverse events like skin irritation or secondary pressure points. This contrasts with removable cast walkers, which often cause discomfort or poor compliance due to bulkiness or inadequate fit (Bus et al., 2020).The absence of adverse events and the lack of ulcer recurrence at three-month follow-up highlight the orthosis's safety and potential for preventive use, addressing a key challenge in diabetic foot ulcer management, where recurrence rates can reach 40% within one year (Bus et al., 2020). The concurrent wound care and glycaemic control optimization likely synergized with the orthosis to enhance healing, emphasizing the importance of a multidisciplinary approach. However, the physiological cost index (PCI) could not be fully assessed pre-intervention due to crutch use, limiting baseline energy expenditure comparisons. Post-intervention PCI normalization suggests reduced metabolic demand, consistent with improved gait efficiency, but further studies with complete pre- and post-intervention PCI data are needed to quantify energy benefits. Comparatively, the modified PTB orthosis offers advantages over other offloading modalities. For instance, off-the-shelf therapeutic footwear, which failed to heal the ulcer in this case, often provides insufficient pressure reduction in patients with neuropathy or deformities (Wu et al., 2008). The custom-moulded design of the PTB orthosis addressed the patient's specific anatomical needs, such as absent plantar sensation and mild swelling, ensuring precise offloading. Additionally, the orthosis's ability to support ambulation during both stance and swing phases, facilitated by the rocker sole, distinguishes it from static devices like TCCs, which primarily address stance-phase pressure. The paediatric context of this case further underscores the orthosis's adaptability, as its lightweight and cosmetic design enhanced compliance in a young patient, a population where comfort and aesthetics are critical for adherence (Graham et al., 2008).

Limitations of this case study include its single-subject design, which restricts generalizability to broader populations with diabetic foot ulcers. The patient's young age, motivated family support, and absence of severe comorbidities may have contributed to high compliance and favourable outcomes, which may not be replicable

in older adults or patients with complex conditions like peripheral vascular disease. Additionally, the lack of a control group or comparison with other offloading methods, such as TCCs or felted foam, limits the ability to definitively attribute outcomes to the PTB orthosis alone. The short follow-up period of three months, while sufficient to confirm initial healing and no recurrence, does not address long-term durability or recurrence risk beyond this timeframe. Future research should focus on multicentre studies with larger cohorts to validate the efficacy of modified PTB orthoses across diverse patient profiles, including adults and those with comorbidities. Incorporating advanced technologies, such as in-shoe pressure sensors or wearable gait monitors, could provide real-time data on offloading efficacy and gait dynamics, enhancing orthotic design optimization (Cavanagh & Bus, 2010). Long-term studies are also needed to assess the orthosis's role in preventing ulcer recurrence, particularly given the high recurrence rates in diabetic populations. In conclusion, the modified PTB orthosis represents a promising intervention for managing refractory plantar foot ulcers, particularly in paediatric patients with diabetic neuropathy. Its ability to achieve complete healing, reduce pain, improve gait, and enhance functional independence, while maintaining high tolerability and safety, positions it as a valuable alternative to conventional offloading methods. Clinicians should consider integrating modified PTB orthoses into multidisciplinary care plans, alongside wound management and glycaemic control, to optimize outcomes in complex cases. Further research is essential to establish standardized protocols and long-term efficacy, paving the way for broader adoption in clinical practice.

CONCLUSION

This case report demonstrates that the modified patella tendon weight-relieving orthosis is a highly effective solution for non-healing ulcer foot, offering rapid wound healing, restored function, reduction in pain, and improved patient independence. It represents an important option, especially when total contact cast or surgical interventions are contraindicated.

The custom-moulded modified patella tendon bearing (PTB) orthosis proved highly effective in managing a refractory 2.5 x 3 cm plantar foot ulcer in a 13-year-old male with diabetic neuropathy. Over a three-month intervention, the orthosis facilitated complete ulcer healing by week 10, reduced pain during ambulation from 6/10 to 2/10 on the VAS, and significantly improved gait parameters, including step length (from 32 ± 5 cm to 44 ± 7 cm), stride length (from 61 ± 10 cm to 89 ± 6 cm), and cadence (from 72 to 95 steps/min). The patient achieved independent ambulation without crutches by week 6, resumed school and light physical activities, and reported high device tolerance with no adverse events, such as skin irritation or secondary pressure points. The absence of ulcer recurrence at three-month follow-up highlights the orthosis's potential for both therapeutic and preventive applications. These findings suggest that the modified PTB orthosis is a viable alternative to traditional offloading methods, offering superior comfort, mobility, and compliance, particularly for pediatric patients with complex foot ulcers. Further research in larger cohorts is warranted to validate its efficacy and establish long-term outcomes in diverse populations.

Ethical Considerations Compliance with ethical guidelines This study was approved by the Ethics Committee of Department of Prosthetics and Orthotics, Utkal University, Bhubaneswar, India.

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Authors' contributions All authors equally contributed to preparing this article.

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