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Abstract

The limited dorsiflexion at the ankle joint is characterized by Equinus deformity. It has a large impact on mobility and functionality at all ages. Usually, Achilles tendon stretching and Ankle Foot Orthosis (AFOs) are used as a treatment but have low efficiency and flexibility. Frequently adjustment to AFOs required through dynamic foot positioning makes this treatment very expensive due to repeated molding. An experimental research design was used to measure plantar flexion angles with a goniometer at many follow-ups. This research showed that a decreased plantar flexion angle, this study indicated the effectiveness of locally made adjustable ankle joints. Developing an adjustable ankle joint addresses both the practical and economic challenges of traditional orthotic treatments. This innovation not only provides clinical outcomes but also expands the opportunity to care for patients with equinus deformity. This adjustable joint gives a flexible and cost-effective solution and improves the management of equinus deformity.

Keywords: Ankle Foot Orthosis (AFO), Ankle Joint, Dorsiflexion, Equinus Deformity, Plantarflexion, Local Made Ankle Joint

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Title

Innovation of Adjustable Ankle Joint Orthoses for Patients with Flexible Equinus Deformity

Abstract

The limited dorsiflexion at the ankle joint is characterized by Equinus deformity. It has a large impact on mobility and functionality at all ages. Usually, Achilles tendon stretching and Ankle Foot Orthosis (AFOs) are used as a treatment but have low efficiency and flexibility. Frequently adjustment to AFOs required through dynamic foot positioning makes this treatment very expensive due to repeated molding. An experimental research design was used to measure plantar flexion angles with a goniometer at many follow-ups. This research showed that a decreased plantar flexion angle, this study indicated the effectiveness of locally made adjustable ankle joints. Developing an adjustable ankle joint addresses both the practical and economic challenges of traditional orthotic treatments. This innovation not only provides clinical outcomes but also expands the opportunity to care for patients with equinus deformity. This adjustable joint gives a flexible and cost-effective solution and improves the management of equinus deformity.

Keywords: Ankle Foot Orthosis (AFO), Ankle Joint, Dorsiflexion, Equinus Deformity, Plantarflexion, Local Made Ankle Joint

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Contents

Introduction

Foot deformities are a type of physical disability that may notably restrict a person's mobility, functionality, and quality of life. In Pakistan, the prevalence of foot deformities varies depending on the population and conditions studied. These deformities can be congenital, which means they were present at the beginning or acquired as a result of any injury or disease.

Foot deformities have an important impact on an individual's potential to walk, carry out day-to-day duties, and participate in social and financial activities.

The foot is an essential part of body weight support, balance, and movement. Deformities of the foot and ankle often cause pain and discomfort, limiting mobility and making it difficult to complete daily tasks. This limitation can lead to a lack of physical activity which can increase the risk of cardiovascular diseases, weight problems, and other health care issues. Additionally, foot deformities can impair balance, resulting in common falls and injuries. The inability to take part in social and economic activities may have psychological outcomes, which include emotions of isolation, tension, depression, and anxiety.

Among the many kinds of ankle and foot deformities, Equinus deformity is the one of serious orthopedic conditions that causes limited dorsiflexion at the ankle joint. This deformity presents considerable challenges, affecting humans of all ages and inflicting some musculoskeletal complications.

Equinus deformity is treated with the use of different techniques. The treatment might be surgical or non-surgical, non-surgical treatments like serial casting, physical therapy, assistive technology, and AFOs, which are selected according to the condition and severity of the deformity.

Individuals with equinus deformity can benefit from assistive devices like walkers, crutches, and canes to maintain mobility and independence. These tools offer additional support and stability, making it easier to walk and carry out daily tasks. and Orthotic Solutions: Orthotic devices, also known as orthoses, are custom-made or off-the-shelf supports that help to align, support, correct, or improve the function of a body part. Ankle-foot orthoses (AFOs) are a popular conservative treatment for equinus deformities. (fig 1)

Figure 1

Solid Ankle Foot Orthosis

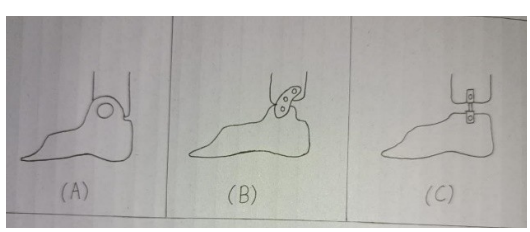
(Chen, W.et. al 2017)Ankle-foot orthoses (AFO) are thought to be an effective conservative treatment for preventing the progression of equinus deformities because they limit ankle plantar flexion and provide passive stretching for tight soft tissues. [2,9-12] Most AFOs keep the ankle in a neutral position but do not allow for adjustable stretching of tight muscles or tendons. So, for this problem, dynamic AFO is the best option.

Romkes, J., & Brunner, R. (2002) The dynamic AFO (d-AFO) has been shown to influence abnormal joint motions through changes in spastic reflexes and underlying muscle tone via tone-reducing features [3], [4]. Another reported benefit of a d-AFO is that it provides maximum mid-line stability and movement control while allowing for freedom of movement [4].

Components of a Dynamic Ankle Foot Orthosis (d-AFO) *(fig 2)*: Ankle Joint: A crucial component that allows controlled movement at the ankle. There are several types of ankle joints used in AFOs

Figure 2

(A): overlap joint, (B): Oklahoma joint, and (C): Gillette joint. Types of commonly used plastic ankle foot joints



Currently, there are three types of ankle joints on the market: The Overlap joint, the Oklahoma joint, and the Gillette joint. The Overlap joint costs approximately 8,000 PKR, the Oklahoma joint around 10,000 PKR, and the Gillette joint up to 15,000 PKR. Despite their effectiveness, these joints are prohibitively expensive for many patients who require such medical devices. This financial barrier frequently prevents patients from receiving the necessary care to improve their mobility and quality of life.

To address this significant issue, I created a locally designed ankle joint for only 300 PKR. Because of its lower cost, a much broader range of patients can advantage of it, ensuring that more humans can afford the required medical care.

The adjustable ankle joint evolved in this study uses modern material and gives a dynamic range of motion that can be adjusted to the exact degree of plantar flexion angle in each case. This newly developed joint target is to improve overall functionality, mobility, and clinical outcomes.

This research investigates the results that allow me to determine the clinical efficacy of the adjustable ankle joint for equinus deformities patients. My goal is to determine how effectively this new joint can work in a patient's life. Also, my ultimate aim of this study is to provide valuable care to patients that can improve their quality of life with a very low-cost orthotic treatment.

I would like to push the boundaries of existing orthotic design as I begin this journey of orthotic innovation. Almost every time, patients with equinus deformity cannot find customized, flexible solutions to meet their needs with the interventions that currently exist. The present landscape lacks a versatile and innovative ankle joint that can be tailored to each individual's unique bio-mechanical condition, preventing optimal patient outcomes. There is a strong need for orthotic research and development to create an adjustable ankle joint that not only corrects equinus deformity but also allows for dynamic, personalized adjustments according to the needs of the individual.

This research seeks to fill a significant gap in orthotic technology by investigating the feasibility and effectiveness of an innovative, adjustable ankle joint. My ultimate goal is to make this solution both affordable and effective by increasing the overall functionality, comfort, and independence of patients with equinus deformity. I hope to bring in a new era of adaptive and effective solutions to this orthopedic condition by conducting accurate scientific research and committing to innovation.

Figure 3

Locally made ankle joint

Literature Review

(Lora-Millan, J. S.et al. 2023) One of the main functions of human beings is locomotion, which is also necessary for a high standard of living. Human locomotion is limited by a variety of (neurological or muscular) factors, particularly those that affect gait efficiency and effectiveness. The muscles connected to the ankle joint are among the many multi-body segments and muscles used in walking that play a significant role in carrying out the necessary mechanical work.

(Maas, J. C., et al.2012) About half of children with spastic cerebral palsy (CP) have deficits in their lower extremity range of motion. These disabilities may eventually result in joint malformations and abnormalities in the children's gait, which would impair their mobility. Reducing joint deformities and secondary activity limitations requires preventing a loss of range of motion. Maintaining a prolonged range of motion during rest may be accomplished by enforcing orthotic management on the muscles.

(Kindregan, D. et. al 2015) Toe walking is a gait deviation characterized by early forefoot ground contact and excessive ankle plantarflexion throughout the gait cycle (GC). It manifests in structural pathologies, neurological or neuromuscular disorders, and autism spectrum disorders [1]. Although toe walking may occur briefly during normal gait development [2], the persistence of this walking pattern after three years of age, with no known cause, is known as Idiopathic Toe Walking (ITW). Some authors have stated that children with ITW can walk normally when asked [3]. As a result, children diagnosed with ITW can be described as typically developing, walking on their toes rather than heel-to-toe. The evidence on the effectiveness of interventions in reducing toe walking is inconsistent, and it does not support the development of clear and unambiguous ITW management guidelines [9]. Moreover, potential limitations and side effects must be considered: children must actively adhere to conservative therapies; some children experienced calf muscle pain after Botulin toxin A injections; and visible AFOs and casts may have a social impact on children and families [11]. As a result, for the time being, the feasibility and potential to reduce the side effects of limiting toe walking and daily activities may influence the selection of a correction approach.

(Kobayashi et al. 2018) An AFO's ability to resist plantarflexion and resistance to dorsiflexion are important mechanical characteristics that may impact the kinematics and kinetics of lower-limb joints during walking. To restrict pathological motion of the ankle during gait, such as excessive equinus in stance and foot drop in swing, an AFO must be sufficiently rigid to resist the ankle's plantarflexion force. Resistance to plantarflexion is also important in preventing knee hyper-extension during stance (Kobayashi et al., 2018). However, excessive resistance to plantarflexion can exacerbate knee flexion during the first rocker of gait.

(Bennett, B. C. et al. 2012). Several studies have investigated the effects of AFOs on the gait of children with CP. Many of these studies found that using AFOs improved gait slightly but significantly. Wearing AFOs increased stride length when compared to walking barefoot, according to studies of both spastic di- and hemiplegic subjects.

(Chen W et al. 2017) conducted a study of equinus deformity assisting with adjustable ankle joint orthosis, indicating that the heel/forefoot ratios for the TD children were 1.41 0.26; 0.65 0.44, 1.02 0.41, and 1.24 0.51 for the splint-assisted AFO correction before and after 6-month and 12-month treatments; and 0.59 0.37, 0.67 0.44, and 0.66 0.42 for the static AFO correction before and after 6-month and 12-month treatments.

(Burndge et al. 1997). The mechanism behind the deformity's formation is complex, but it is thought to be a result of the combination of 1) an incorrect strength ratio of the dorsiflexor muscles to the plantar flexor muscles because of plantar flexor muscle stiffness, 2) an inability to generate enough force in the dorsiflexor muscles that results in dorsiflexion, and 3) an inability of the plantar flexor muscles to eccentrically lengthen to allow dorsiflexion to occur.4). co-activation of the foot's dorsiflexor and plantar flexor muscles at inconvenient times during the gait cycle, or 5) an unknown cause leading to an equinus deformity. In his thesis, stroke patients will be defined operationally as having an equinus deformity of the foot if they: 1) have the inability to actively dorsiflex their ankle, 2) are wearing or have a previous history of wearing ankle foot orthoses (AFO), or 3) have been referred by a physiotherapist who considers they would benefit from wearing an AFO. Every year, there are between 298 and 596 stroke patients in the Republic of Ireland

(Verdie et al. 2004). Patients who develop this deformity need more specialized, demanding; and long-term rehabilitation than those who do not develop it

(Westberry et al. 2007). Foot and ankle radiographs taken with the individual barefoot and while carrying the brace showed significant differences in all segmental alignment measurements (p 0.05). These differences were minor (6° or 10%), and would be deemed clinically insignificant. In 24% to 44% of the feet, the combined malalignment of equinoplanovalgus (clinical flatfoot) required radio graphic correction of at least one part (hind-foot, mid-foot, or forefoot) to within the normal range. In 5% to 20% of feet, the combined malalignment of equinocavovarus (clinically high-arched foot) was corrected with at least one segment falling within the normal range.

(Davids Jon et al., March 2007). Orthoses are commonly used to assist youngsters who have cerebral palsy in improving their gait. The biomechanics of the foot and ankle during normal gait, the pathophysiology and pathomechanics of gait disruption in children with cerebral palsy, and the biomechanical properties of various orthoses are all necessary for making the best clinical decisions for improving gait through orthotic management. The clinician's goals must be aligned with those of the child and family, the therapist, and the orthotist. When choosing an Orthosis, consider the design, indications, and price. The physician can develop a clinical decision-making framework by focusing on ankle/foot alignment, range of motion, and dynamic gait deviations.

(Kinsella et.al 2008). Following a stroke, patients may develop an equinus deformity of the foot, which can alter their gait pattern. Sub-classification of gait patterns in these patients would help develop and deliver more targeted treatment. A hierarchical cluster analysis was used to classify the gait patterns of 23 chronic stroke patients with foot equinus deformity using temporal distance parameters as well as joint kinematic and kinetic measures in the sagittal and coronal planes. Cluster analysis revealed that gait patterns were not uniformly homogeneous, and three subgroups with within-group homogeneous levels of function were discovered. Further investigation revealed significant differences in some of the temporal distance, kinematic, and kinetic measures tested.

Materials and Methods

An experimental study was formulated to narrow down the particular clinical results. I gathered their data from ABL (Accessibility beyond limitations). The study's sample size was limited to 3 patients, allowing for detailed experimental research focused on foundational data collection. Follow-up measurements were conducted precisely to assess improvements in ankle angles using a jointed ankle-foot Orthosis. Patients in the hospital were selected using a random sampling method to obtain subjects for the study. The research was implemented for 6 months after the approval of the synopsis and 9 weeks of follow-up period. A tool utilized in the study was a goniometer, used for angle measurement. Inclusion criteria were Both genders were included. They were no older than 15 years. They were currently healthy. They could walk 10 meters on their own. Had not had any lower-limb joints replaced. They did not have severe arthritis in their ankles, knees, or hips.

They did not experience excessive shortness of breath while walking short distances. They had no lower-limb injuries at the time of testing that could have affected their ability to walk. Did not have diabetes mellitus. Did not have renal or kidney dysfunction. Did not have high blood pressure issues. Did not have metabolic disorders, acute myocardial infarction, uncontrolled cardiac arrhythmia, active endocarditis, symptomatic severe aortic stenosis, or acute pulmonary disorder.

The exclusion criteria w**ere** Older than 15 years old. Could not able to walk.Involved in other deformities e.g. hip and knee deformities.

Participants

Table 1

Participant	Gender	Age	Initial condition	Treatment
1	Female	4	Correctable equinus deformity with the foot at 20 degrees plantarflexion.	Local-made adjustable ankle joint
2	Male	7	25 degrees plantarflexion at the foot	Local-made adjustable ankle joint
3	Male	13	30 degrees plantarflexion.	Local-made adjustable ankle joint

Results

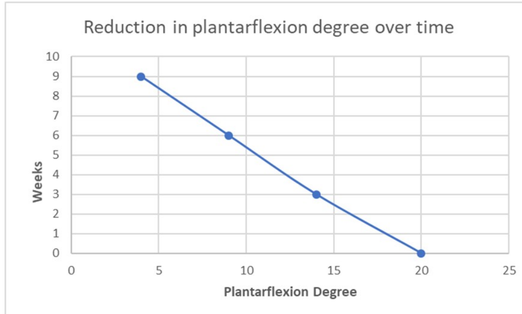
1st participant

Initial: 20 degrees plantarflexion 1st Follow-up (3 weeks): 14 degrees plantarflexion (reduction of 6 degrees)

2nd Follow-up (6 weeks): 9 degrees plantarflexion (reduction of 5 degrees)

3rd Follow-up (9 weeks): 4 degrees plantarflexion (reduction of 5 degrees)

Figure 4



2nd Participant

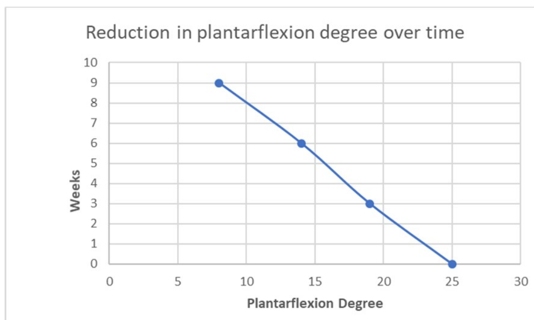
Initial: 25 degrees plantarflexion

1st Follow-up (3 weeks): 19 degrees plantarflexion (reduction of 6 degrees)

2nd Follow-up (6 weeks): 14 degrees plantarflexion (reduction of 5 degrees)

3rd Follow-up (9 weeks): 8 degrees plantarflexion (reduction of 6 degrees)

Figure 5



3rd participant

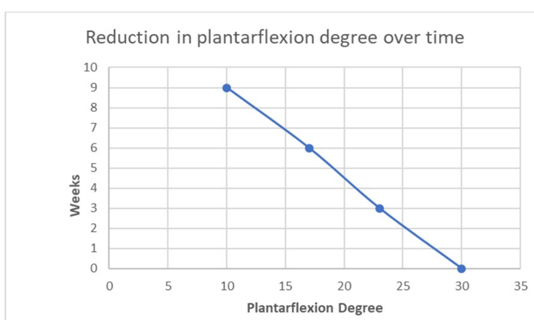
Initial: 30 degrees plantarflexion

1st Follow-up (3 weeks): 23 degrees plantarflexion (reduction of 7 degrees)

2nd Follow-up (6 weeks): 17 degrees plantarflexion (reduction of 6 degrees)

3rd Follow-up (9 weeks): 10 degrees plantarflexion (reduction of 7 degrees)

Figure 6



Discussion

This thesis focuses on the efficacy of a newly innovative, low-cost adjustable ankle joint in the treatment of equinus deformity, thereby filling an essential role in low-cost orthotic options. This study tested the joint's effect on reducing plantar-flexion angles in contributors over nine weeks, comparing the results to the present literature and emphasizing the capacity implications for scientific practice.

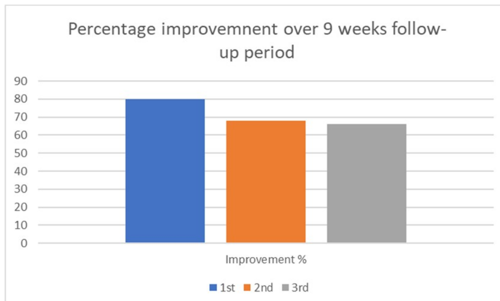
Findings and Interpretation

During the investigation for research follow-up periods, every single participant showed significant improvements in plantarflexion angles at the foot. The 1st participant improved by 30% after 3 weeks, and afterward, follow-up showed consistent 25% improvements of 80% over the period of 9 weeks.

Likewise, the 2nd participant also showed a decrease in angles of plantarflexion which resulted in an improvement of a total of 68% at the last follow-up.

Similarly, 3rd participant showed a 66.67% improvement in the plantarflexion angle of the foot over the 9 weeks of the follow-up period.

Figure 7



Comparison with Existing Literature

The findings are matched with previous research highlighting the importance of dynamic, patient-targeted orthotic devices. Existing static AFOs frequently lack the adjustability needed to accommodate adjustments in patient conditions over time, whereas dynamic AFOs have been validated as powerful in improving gait, mobility, and independence through adjustable resistance tiers (Kobayashi et al.2018; Chen et al.2017).

Our findings support these principles by proving that an adjustable ankle joint can achieve results comparable to more expensive market options, thereby improving treatment adaptability and patient outcomes.

Clinical Implications

Using a goniometer provided accurate measurements of plantar-flexion angles, taking into consideration an accurate evaluation of the efficacy of orthotic interventions. This quantitative research is regular with established methodologies in orthotic studies, strengthening our findings extra reliable.

Future Research Directions

Future studies will have Larger sample lengths and longer follow-up periods need to be utilized in future studies to verify the findings about joint durability, reliability, and affected person satisfaction. Further to that, expanding the have a look at to consist of a broadened range of patient demographics and levels of equinus deformity would improve the findings and effect of the innovative ankle joints on the affected person's life.

Conclusions

This study highlights the great advantages of a modern, low-cost adjustable ankle joint for people with equinus deformity. This intervention represents a greater step in the direction of customized orthotic care by means of making an allowance for dynamic changes based on individual-affected person requirements. The findings indicate that this locally developed joint is simply as effective as expensive ankle joints, overcoming the practical and financial issues associated with traditional orthotic treatments.

This advancement no longer only increases patient access to necessary care, however, it additionally improves the overall quality of life of affected individuals by efficaciously addressing mobility challenges. This study focused on the adjustable joint's ability to improve treatment effects even as ultimately price-effective, making it a promising addition to existing orthotic strategies.

Future studies should emphasize on increasing the sample size and evaluation length to validate these findings and look at much wider possibilities in orthopedic care.

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