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A Case Study on Proximal Femoral Focal Deficiency (PFFD)

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ABSTRACT

PFFD is a rare congenital condition characterised by underdevelopment of the proximal part of the femur, leading to significant limb length discrepancies & functional limitations. A new endoskeletal ortho-prosthesis with shock-absorbing pylon is suitable for fitting patients with PFFD. This device is specially focused on absorbing impact forces while walking or other weight bearing activities, reducing stress on the joints and improving comfort. It provides support, improves stability and enhance mobility for the affected limb.

Keywords: PFFD, Shock-absorbing pylon, Ortho-prosthesis.

INTRODUCTION

The study focuses on the application of a shock-absorbing pylon in ortho-prostheses for individuals with Proximal Femoral Focal Deficiency (PFFD)—a rare congenital condition characterized by the partial or complete absence of the proximal femur [1]. This abnormality leads to limb shortening, joint deformities, and reduced mobility, significantly affecting the individual's ability to walk and maintain balance [2]. PFFD can occur unilaterally (affecting one leg) or bilaterally (both legs), with varying degrees of severity that impact the hip and knee joints. Since the thigh bone (femur) plays a crucial role in weight-bearing and movement, its deficiency creates major functional impairments that require prosthetic intervention to restore mobility [3].

Traditionally, extension prostheses made of wood or resin laminates have been prescribed for PFFD patients [4]. While these prostheses provide basic structural support, they do not offer sufficient shock absorption or dynamic control, making it difficult for users to achieve a smooth and energy-efficient gait cycle. Due to weakened muscles and abnormal weight distribution, patients often experience instability, discomfort, and excessive energy expenditure while walking, leading to fatigue, joint stress, and long-term musculoskeletal complications [5].

Additionally, conventional prosthetic designs do not effectively absorb ground reaction forces, which can result in pain and reduced prosthesis acceptance by users [6].

To address these challenges, the study introduces a shock-absorbing pylon, an innovative prosthetic component designed to enhance comfort, stability, and mobility for PFFD patients [7]. The pylon incorporates a spring mechanism that acts as an energy storage and dissipation system, allowing it to absorb impact forces during heel strike and release stored energy during push-off. This biomechanical advantage helps create a smoother, more natural gait pattern, reducing the shock transmitted to the residual limb and joints [8]. By distributing forces more evenly, the pylon minimizes pressure points, improves balance, and enhances the overall functionality of the ortho-prosthesis [9].

Fig:1. Unilateral PFFD

This study investigates the efficacy of integrating the shock-absorbing pylon into PFFD ortho-prostheses by examining its design, fabrication, and clinical impact. Through experimental trials, the research evaluates whether the spring-loaded mechanism effectively reduces pain, increases mobility, and improves gait efficiency compared to traditional prosthetic designs. The findings of this study aim to contribute to advancing prosthetic technology, offering PFFD patients a more comfortable and functional mobility solution that improves their quality of life and long-term prosthetic outcomes [10].

MATERIALS AND METHODS

Fig:2. Spring

Fig:3. Pylon

Fig:4. Socket adopter

Fig:5. Prosthetic Foot

Fig:6. Foot Adopter

The study followed a structured and methodical approach to ensure a comprehensive evaluation of the shock-absorbing pylon in ortho-prostheses for PFFD patients. The study was designed to focus on key parameters such as prosthetic functionality, patient comfort, and gait efficiency, while also considering the feasibility of incorporating this innovation into existing prosthetic designs.

To achieve this, specific inclusion and exclusion criteria were set to select suitable participants for the study. The inclusion criteria required participants to be unilateral PFFD patients aged between 15 and 28 years, as this age group represents individuals who are physically active and likely to benefit from improvements in prosthetic technology. The exclusion criteria eliminated individuals who were unable to tolerate or use a prosthesis due to medical complications, severe muscular weakness, or other biomechanical limitations that could interfere with accurate assessment.

The prosthetic design was carefully structured to integrate various functional components aimed at enhancing stability, mobility, and comfort for the user. The ortho-prosthesis consisted of several key elements:

Shock-absorbing Spring: A crucial feature that helps absorb impact forces generated during walking, reducing stress on the residual limb and joints.

Pylon: Acts as the structural link between the socket and the prosthetic foot, ensuring proper weight distribution and alignment during ambulation.

Socket: Designed to provide optimal support and stability, particularly for PFFD patients with limited femoral structure. This socket ensures that the body weight is transferred efficiently to the prosthetic limb without causing discomfort or instability.

The fabrication process of the prosthesis followed a step-by-step methodology involving casting, mould modifications, component assembly, and socket lamination. Initially, a custom mould of the residual limb was created using Plaster of Paris (POP) bandages, ensuring a precise and comfortable fit for the patient. The shock-absorbing pylon was then designed by incorporating a spring mechanism within a metal rod, allowing for energy storage and controlled dissipation during different phases of the gait cycle. The assembled prosthesis was subjected to clinical trials, where it was tested for comfort, gait efficiency, impact absorption, and overall user satisfaction.

These trials aimed to determine whether the integration of a shock-absorbing pylon led to significant improvements in prosthetic performance compared to traditional designs.

Fig:7. Ortho-prosthesis with shock-absorbing pylon

Fig:8. Fabrication Process

RESULTS & FINDINGS

The clinical trial results demonstrated significant improvements in the functionality and comfort of ortho-prostheses equipped with a shock-absorbing pylon for individuals with Proximal Femoral Focal Deficiency (PFFD). The prosthetic innovation was assessed based on key performance indicators, including pain reduction, gait efficiency, mobility, and impact absorption, all of which play a crucial role in determining the overall usability and acceptance of the prosthesis by patients. The results were overwhelmingly positive, indicating that the incorporation of a shock-absorbing pylon could be a game-changer in improving the quality of life for individuals with limb deficiencies.

One of the most significant findings was the reduction in pain and discomfort experienced by participants. Traditional rigid prostheses often cause high levels of stress on the residual limb, leading to fatigue, joint strain, and discomfort, particularly during prolonged ambulation. However, with the shock-absorbing pylon, participants reported less pain and fatigue, as the spring mechanism helped in dampening excessive forces during heel strike and transition phases of the gait cycle. This reduction in impact stress allowed users to walk more comfortably for longer durations, significantly enhancing their overall endurance and mobility.

Another notable improvement observed was in gait stability and efficiency. The shock-absorbing pylon facilitated smoother weight transitions by absorbing and redistributing kinetic energy, which in turn reduced the stress on joints and improved postural balance. This mechanism allowed for a more natural walking pattern, minimizing the abrupt movements that are often seen in individuals using traditional prosthetic limbs. As a result, participants found it easier to maintain balance and coordination, reducing the risk of falls and injuries.

The study also highlighted a notable increase in mobility and confidence among users. One of the major challenges faced by PFFD patients is excessive energy expenditure while walking, which can make daily activities exhausting and difficult to sustain. With the incorporation of the shock-absorbing pylon, users required less effort to move, making routine tasks such as climbing stairs, walking on uneven surfaces, or standing for extended periods much easier and more manageable. This boost in functional independence directly contributed to higher confidence levels, as patients felt more secure and in control while using the prosthesis.

Lastly, the spring mechanism of the shock-absorbing pylon played a crucial role in mitigating ground reaction forces, thereby reducing residual limb strain and potential long-term musculoskeletal complications. The prosthesis efficiently distributed the impact energy across the limb, preventing localized pressure buildup that could otherwise cause pain, skin breakdown, or secondary complications. This enhanced shock absorption not only improved short-term comfort but also ensured the long-term health and sustainability of the patient's prosthetic use.

These findings strongly suggest that the integration of a shock-absorbing pylon can significantly enhance the functionality, comfort, and overall experience of prosthetic users, paving the way for more advanced and adaptive prosthetic designs that cater to the dynamic needs of individuals with PFFD. The study further reinforces the need for continued innovation in prosthetic engineering, aiming to create lighter, more efficient, and biomechanically optimized prosthetic solutions for individuals with lower limb deficiencies.

Fig:9. Alignment and trial of Ortho-prosthesis

DISCUSSION

While the study demonstrates clear benefits, some limitations exist:

Customization Challenges: The pylon's effectiveness depends on the patient's weight, activity level, and limb condition, requiring personalized adjustments.

Material Durability: The spring mechanism may degrade over time, requiring periodic maintenance or replacements.

Limited Long-term Data: The study provides short-term benefits, but long-term wear and tear effects need further investigation.

Despite these challenges, the results strongly indicate that shock-absorbing pylons could revolutionize prosthetic designs for PFFD patients by providing a more efficient and comfortable walking experience.

CONCLUSION

The study successfully demonstrated that incorporating a shock-absorbing pylon significantly improves gait mechanics, comfort, and overall mobility in PFFD patients. The innovation has the potential to become a standard component in future ortho-prosthetic designs. However, further research is required to refine material durability, customization techniques, and long-term performance.

Declaration by Authors

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