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Affordable Multi-Axial Adjustable Socket for Immediate Post-Operative Prosthesis: Enhancing Early Rehabilitation in Developing Countries

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ABSTRACT

Transfemoral amputation, the surgical removal of the leg above the knee, is performed when the limb is severely damaged due to trauma, infection, or tumours. Limb loss is a life-altering event, impacting both physical mobility and psychological well-being. A well-fitting prosthetic socket is crucial for successful rehabilitation. However, by the time patients seek prosthetic care, typically 2–3 years post-amputation, their residual limb undergoes significant changes, including contractures, edema, uneven muscle atrophy, and phantom limb sensations. These changes contribute to a poor socket fit, prolonged gait training, and increased rehabilitation time.

Immediate postoperative prostheses (IPOP) can mitigate these issues by providing early weight-bearing and mobility. However, their limited use is attributed to frequent socket modifications due to residual limb volume fluctuations, high costs, and fabrication challenges. To address these limitations, we propose a novel prosthetic socket design that accommodates volume changes, allowing for continuous use throughout the recovery phase. This innovation aims to enhance early rehabilitation, reduce costs, and improve patient confidence in ambulation.

Keywords: Transfemoral amputation, prosthetic socket, residual limb volume, immediate postoperative prosthesis, rehabilitation.

INTRODUCTION

The human-prosthesis interface, most commonly a personalised ‘socket’, is often identified as one of the most essential components of prosthesis [1]. Despite being personalised, prosthetic sockets are often identified as the most problematic prosthetic component for users [2, 3]. Residual limb volume fluctuations, which can be caused by diet and activity level [4], comorbidities such as diabetes, or dialysis, or more long term residual limb changes such as muscle atrophy and growth in a child, mean that the fit of fixed geometry sockets will inevitably alter over time [5]. Residual limb volume fluctuations are larger for individuals with lower-limb amputations.

Rehabilitation following limb loss is a complex process, with the prosthetic socket

being the most critical component in ensuring functional mobility and comfort. Typically, patients seek prosthetic care only after the surgical site has healed, which can take several months to years. During this period, the residual limb undergoes various changes, such as contractures, edema, muscle atrophy, restricted range of motion (ROM), phantom limb pain, and altered posture due to shifts in the body's center of gravity [6-8]. These changes often result in a poor initial fit of the definitive prosthesis, leading to prolonged rehabilitation and gait training. Additionally, the absence of weight-bearing activity for extended periods makes it difficult for patients to adapt to a prosthetic limb, further delaying their return to independent mobility.

To address these challenges, an Immediate Postoperative Prosthesis (IPOP) is recommended to facilitate early rehabilitation. However, its widespread adoption is limited due to factors such as the need for frequent adjustments as the residual limb changes in volume, high costs associated with multiple prosthetic modifications, and the time required for fabrication. As a result, most patients receive their definitive prosthesis years after amputation, by which time muscle contractures and postural imbalances may have already developed.

To overcome these limitations, this study proposes a novel prosthetic socket design that accommodates residual limb volume fluctuations, allowing a single socket to be used throughout the recovery phase. This innovative approach aims to enhance patient comfort, reduce rehabilitation time, and improve overall prosthetic outcomes by promoting early mobility and weight-bearing activity.

Aim:

The primary aim of this research is to develop a prosthetic socket design that accommodates residual limb volume changes during the post-amputation recovery phase, enabling continuous use of a single socket and facilitating early rehabilitation. This innovation seeks to improve patient outcomes by promoting early mobility, reducing rehabilitation time, and preventing common post-amputation complications.

Objectives:

- Prevent Contracture of the Residual Limb – Ensure early weight-bearing and controlled movement to minimize the risk of muscle contractures due to prolonged inactivity.
- Prevent Bed Sores – Reduce prolonged pressure on specific body areas by encouraging early mobility, thus preventing pressure ulcers in bedridden patients.
- Maintains Erect Posture – Support proper postural alignment and prevent postural imbalances by providing early prosthetic intervention.
- Enhance Psychological Confidence – Boost patient morale and confidence by enabling early mobility and reducing dependence on caregivers.
- Facilitate Better Wound Healing and Prevent Edema – Promote controlled loading on the residual limb, enhancing circulation and reducing swelling for optimal healing.
- Reduce Phantom Limb Sensation and Pain – Aid in desensitization of the residual limb, potentially decreasing the occurrence and severity of phantom limb sensations.
- Reduce Time Required for Gait Training with the Definitive Prosthesis – Familiarize patients with prosthetic use early in their recovery, leading to a smoother transition to the definitive prosthesis.
- Enable Early Ambulation – Provide patients with the ability to stand and walk soon after surgery, reducing muscle atrophy and improving mobility outcomes.
- Prevent Postoperative Complications – Minimize risks of thromboembolism, pneumonia, and other postoperative

complications by promoting early movement and weight-bearing activities.

MATERIALS & METHODS

A 51-year-old male with a right-sided transfemoral (TF) amputation was fitted with the newly designed multi-axial adjustable socket at NILD, Kolkata. The socket was fabricated using 12 mm polypropylene (PP) sheet following a precise casting and measurement process.

Socket Design and Fabrication - The socket trim lines were designed above conventional ischial containment (IC) trim lines, ensuring enhanced adaptability and comfort.

Anterior Trimline: A 3-inch section was removed along the anterior midline. The distal end was reduced by 0.5 cm (positioned half-inch above the adaptor wings).

Posterior Trimline: Designed symmetrically to the anterior trimline.

Medial Trimline: A 2-inch wall was retained proximally. The middle portion was removed between the right and left cut sections.

Lateral Trimline: The proximal frame remained intact for stability. A 2-inch wall was preserved on both the right and left sides, while the middle portion was cut out.

Adjustability Mechanism: A horizontal slit cut was made to divide the remaining frame into three adjustable sections. Height adjustability was achieved by attaching all the frames with a bar, providing multiple adjustment points. This innovative design allows the socket to accommodate residual limb volume fluctuations during the healing and rehabilitation phase. This design was evaluated for its effectiveness in pre-prosthetic training, early ambulation, and improving patient confidence in a developing-country setting.

Multi-Axial Adjustable Socket

RESULT

The newly designed multi-axial adjustable socket was successfully fitted to a 51-year-old male with a right-sided transfemoral (TF) amputation at NILD, Kolkata. The evaluation focused on comfort, adaptability, early mobility, and rehabilitation efficiency during the post-amputation recovery phase.

Fit and Comfort:

- The adjustable trimlines and height-modification mechanism effectively accommodated residual limb volume

fluctuations, ensuring a comfortable fit throughout different stages of healing.
- The patient reported reduced pressure points and improved limb stability, minimizing discomfort during weight-bearing activities.

Early Mobility and Functional Outcomes:
- The patient was able to stand and ambulate earlier than conventional prosthetic rehabilitation protocols, demonstrating improved balance and posture.
- Contracture prevention was observed due to early controlled weight-bearing and movement, reducing the risk of hip flexion contractures commonly associated with delayed prosthetic use.
- Postural alignment improved as the socket helped maintain the center of gravity (COG), preventing compensatory gait deviations.

Psychological and Sensory Benefits:
- The patient exhibited higher confidence in prosthetic use due to early exposure and training with the adjustable socket.
- Phantom limb sensation and pain were significantly reduced with gradual weight-bearing and desensitization techniques.

Rehabilitation Efficiency:
- The time required for gait training was notably reduced, as the patient adapted more quickly to the prosthesis.
- The transition to the definitive prosthesis was smoother, with minimal adjustments needed due to early functional adaptation.
- Prevention of common post-operative complications, such as thromboembolism, pneumonia, and bed sores, was observed due to early ambulation and mobility.

Cost and Feasibility:
- The single adjustable socket design eliminated the need for multiple socket replacements, reducing financial burden on the patient.
- The fabrication process was simple and cost-effective, making it a viable solution for prosthetic rehabilitation in resource-limited settings.

DISCUSSION

The results of this study demonstrate that the multi-axial adjustable socket offers significant advantages over conventional prosthetic socket designs, particularly in early rehabilitation, comfort, and cost-effectiveness. This innovative design addresses the critical challenge of residual limb volume fluctuations, which commonly lead to poor prosthetic fit and the need for frequent socket modifications. By allowing dynamic adjustments, the socket effectively accommodates limb changes throughout the healing and rehabilitation process, reducing the need for multiple socket replacements.

Clinical Implications:
- The patient's ability to stand and ambulate earlier compared to conventional rehabilitation timelines indicates that this socket design promotes early weight-bearing, reducing complications such as muscle contractures, deconditioning, and postural imbalances.
- The improved postural alignment and stability during ambulation suggest that this design enhances gait biomechanics, reducing the risk of compensatory movement patterns that may lead to secondary musculoskeletal issues.
- The reduction in phantom limb pain and sensations observed in this study aligns with existing evidence that early prosthetic use aids in neuromuscular adaptation and desensitization of the residual limb.

Economic and Practical Benefits:
- The affordability and ease of fabrication of the socket make it an ideal solution for developing countries, where access

to advanced prosthetic technology is often limited due to cost constraints.

- The single-socket approach eliminates the need for multiple prosthetic fittings, which are often financially burdensome for patients and healthcare systems in low-resource settings.
- The design's modular adjustability allows for extended use, ensuring that patients can progress through rehabilitation without the frequent need for socket replacements.

Comparison with Existing Solutions:

- Traditional Immediate Postoperative Prostheses (IPOPs), while beneficial, have limitations due to their fixed socket geometry, which does not accommodate residual limb volume changes.
- Existing adjustable socket technologies are often complex and expensive, making them less accessible in developing countries. This study's simplified, low-cost approach retains adjustability without compromising stability, offering a practical alternative for widespread adoption.

CONCLUSION

This study highlights the potential of a multi-axial adjustable socket in improving early rehabilitation outcomes for transfemoral amputees. By addressing the challenges of socket fit, limb volume fluctuations, and affordability, this novel design enhances early ambulation, psychological confidence, and overall functional outcomes. The cost-effective and easy-to-fabricate nature of the socket makes it particularly suitable for resource-limited settings, where access to advanced prosthetic care remains a challenge.

Future research should focus on expanding clinical trials, involving a larger patient population, and exploring long-term outcomes of this adjustable socket technology. Additionally, integrating more lightweight and durable materials could further optimize the performance and lifespan of this innovative prosthetic solution.

By reducing rehabilitation time, promoting early mobility, and lowering prosthetic costs, this affordable multi-axial adjustable socket has the potential to revolutionize prosthetic care in developing countries, ensuring that amputees regain mobility and independence faster and more effectively.

Declaration by Authors

Ethical Approval: Not Applicable

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REFERENCES

1. Pirouzi G, Abu Osman NA, Eshraghi A, Ali S, Gholizadeh H, Wan Abas WA. Review of the socket design and interface pressure measurement for transtibial prosthesis. Cientific World Journal. 2014; 2014:849073.
2. Paternò L, Ibrahimi M, Gruppioni E, Menciassi A, Ricotti L. Sockets for limb prostheses: a review of existing technologies and open challenges. IEEE Trans Biomed Eng. 2018;65(9):1996–2010.
3. Andrysek J. Lower-limb prosthetic technologies in the developing world: a review of literature from 1994–2010. Prosthet Orthot Int. 2010;34(4):378–98.
4. Sanders JE, Fatone S. Residual limb volume change: systematic review of measurement and management. J Rehabil Res Dev. 2011;48(8):949.
5. Meulenbelt HE, Geertzen JH, Jonkman MF, Dijkstra PU. Skin problems of the stump in lower-limb amputees: 2. Influence on functioning in daily life. Acta Derm Venereol. 2011;91(2):178–82.

6. Ballas, GJ, Ballas, MT. Adaptive compression prosthetic socket system and method. US patent 10357382B2. 2019.
7. Epoch Medical Innovations Inc. Limb air product overview. 2022. https:// www. epoch medic al. com/copy-of-limb air. Accessed 10 Mar 2023.
8. Ballas, GJ, Ballas, MT. Modular adjustable prosthetic volume compensation system. US patent 2022/0110768 A1. 2022.

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