International Journal of Science and Healthcare Research
[Indexed, Peer-Reviewed Journal]
Vol. 10; Issue: 3; July-Sept. 2025
Website: ijshr.com
Case Study *ISSN: 2455-7587*

Comparative Analysis of Thermoplastic and Resin-Laminated PTBSC Sockets on Quadriceps Muscle Profile in a Transtibial Amputee: A Case Study

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DOI: https://doi.org/10.52403/ijshr.20250311

ABSTRACT

Background: Socket design and material significantly affect comfort, function, and muscle engagement in transtibial prosthetic users. This case study compares the influence of thermoplastic and resin-laminated PTBSC (Patellar Tendon Bearing Supracondylar) sockets on the quadriceps muscle profile of a transtibial amputee using surface electromyography (sEMG).

Methods: A 32-year-old male with a right-sided transtibial amputation was fitted with two prosthetic sockets—first with a thermoplastic PTBSC socket and then with a resin-laminated PTBSC socket. Each was worn for three months. EMG activity of the rectus femoris muscle was recorded during controlled knee extension using a surface EMG system. The average of three trials was calculated for each condition.

Results: Mean quadriceps muscle activity for the thermoplastic socket was 0.5467 ± 0.08910, and for the resin-laminated socket, 0.5853 ± 0.08717. No statistically significant difference in muscle activity was observed. However, the patient subjectively reported better comfort, reduced weight, and ease of use with the resin-laminated socket.

Conclusion: Both socket types provided comparable biomechanical support as reflected in muscle activity. The resin-laminated socket, while not superior in EMG performance, was preferred by the user due to better subjective comfort and usability. These findings suggest that socket material selection should consider both functional and user-centered factors to optimize prosthetic outcomes. Further research with larger samples is warranted.

Keywords: Transtibial Amputation, PTBSC Socket, Thermoplastic Socket, Resin-Laminated Socket, Surface Electromyography (sEMG), Quadriceps Muscle Activity, Prosthetic Socket Design, Patient Satisfaction, Rehabilitation Engineering.

INTRODUCTION

Trans-tibial amputations account for 32.8% of traumatic amputations, whereas unilateral transtibial amputation was common at about 85.3%. [1] Another study mentioned that the most common amputation cause was trauma (70.3%) and peripheral vascular disease is the second most common cause. lower limb amputation is the more common amputation than upper limb amputation, accounting for

94.8% of all amputations. According to the National Sample Survey Organization, West Bengal state ranks second in terms of prevalence rate and third in incidence rates of disability among the major Indian states. [2] From a study in 2006, the World Health Organization collected the data from Indian population on trans-tibial amputation prevalence, where it showed that around 16.8 fatal injuries per 100,000 population and 38.9 non-fatal injuries per 100, 000. [3]

The socket is the part of the prosthesis that fits over the residual limb (the remaining part of the amputated leg). It is custom-made to provide a secure and comfortable fit. Different socket designs, such as patellar tendon bearing sockets, total surface bearing sockets, and hydrostatic sockets, are available. [4, 5] The design and fit of the socket can significantly impact the patient's mobility, function, and overall quality of life. Studies have shown that sockets manufactured using computer-aided design/computer-aided manufacturing (CAD/CAM) methods yield better outcomes in terms of walking ability, pain-free walking time, and quality of life compared to traditional socket manufacturing methods. [6, 7]

There are various materials used for transtibial prosthetic sockets, including traditional materials like thermoplastics and composites, as well as newer materials like 3D-printed polymers. Traditional materials such as polypropylene and carbon fiber composites have been widely used due to their strength, durability, and ability to be customized. 3D-printed polymers, such as polylactic acid (PLA), have also been explored as a potential alternative for socket fabrication, offering advantages such as cost-effectiveness and customization options. [8, 9, 10]

Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscle an electromyograph detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. [11] Several studies have investigated the electromyographic (EMG) profile activity in individuals with transtibial amputation (TTA). These studies have examined muscle activation patterns and differences in muscle activity between TTA individuals and able-bodied individuals.

Therefore, this case study aims to comparatively evaluate the impact of thermoplastic and resin-laminated PTBSC (Patellar Tendon Bearing Supracondylar) sockets on the quadriceps muscle profile of a transtibial amputee. By analyzing muscle activity and functional performance across both socket types, the study seeks to determine whether the material properties of the socket influence muscle engagement, stability, and comfort during ambulation. The findings may offer valuable insights for clinicians and prosthetic designers in optimizing socket selection to enhance patient outcomes.

Aim:

To comparatively evaluate the effect of thermoplastic and resin-laminated PTBSC sockets on the quadriceps muscle profile of a transtibial amputee using electromyographic (EMG) analysis.

Objectives:

1. To fabricate and fit thermoplastic and resin-laminated PTBSC sockets for the same transtibial amputee using standardized procedures.
2. To assess and compare the quadriceps muscle activity using surface electromyography (sEMG) while the amputee performs ambulation tasks with each socket.
3. To analyze the influence of socket material on muscle activation patterns, gait stability, and functional performance.
4. To identify any subjective differences in comfort, fit, and usability between the two socket types.
5. To provide clinical insights for material selection in transtibial prosthetic socket design to improve patient outcomes.

MATERIALS & METHODS

A 32-year-old male with a right-sided transtibial (TT) amputation was initially fitted with a transtibial prosthesis incorporating a PTBSC thermoplastic socket. Data were collected after three months of consistent use. Subsequently, the same individual was fitted with a PTBSC resin-laminated socket, and data were similarly recorded following three months of regular use.

Fig 1: Endoskeleton prosthesis with resin laminated socket

Fig 2: Endoskeleton prosthesis with polypropylene socket

Muscle activity:

The subject was shown the assessment positions before the study. An electromyography system (2-channel recording unit) neuropack MEB-9400 was used for surface EMG measurement in this study. This consists of 2 surface electrodes (bar electrode) and 1 ground strap electrode. Each surface EMG electrode was applied to the skin cleaned with an alcohol swap, and the impedance was always controlled at less than 10 kΩ. The rectus femoris muscle surface EMG activity was recorded using bar EMG electrodes.

The placement of the surface electrodes was:

A. Rectus femoris- The electrode for the rectus femoris was placed at 1/2 on the line from the anterior superior iliac spine to the superior part of the patella.
B. A ground electrode placed over the forearm.

The subject was asked to stand on a single leg of the unaffected side and instructed to extend the affected side knee (figs 11-12) for quadriceps muscle activity. The sEMG signals were recorded for 5ms during the position. The test was repeated three times, with at least 3 minutes of rest in between to minimize the effect of fatigue on participants. Maximum amplitude was recorded, and the average value of the three readings was taken to analyze the data.

RESULT

The surface electromyography (sEMG) analysis of the quadriceps (rectus femoris) muscle activity was performed after three months of regular use of each socket type. The mean muscle activity (mean ± SD) with the thermoplastic PTBSC socket was 0.5467 ± 0.08910, while the activity recorded with the resin-laminated PTBSC socket was 0.5853 ± 0.08717. Although the

resin-laminated socket showed slightly higher mean EMG amplitude, no statistically significant difference in quadriceps muscle activation was observed between the two socket types.

In terms of subjective feedback, the amputee reported that the resin-laminated socket felt lighter, more comfortable, and easier to use during routine ambulation.

DISCUSSION

The findings of this case study indicate that while both thermoplastic and resin-laminated PTBSC sockets support adequate quadriceps muscle engagement during movement, the difference in mean EMG activity is not substantial. This suggests that, from a muscle activation standpoint, both materials provide comparable biomechanical support.

However, the subjective preference for the resin-laminated socket highlights an important aspect of prosthetic design: patient-perceived comfort and usability can play a critical role in long-term compliance and functional performance. Resin-laminated sockets are known for their enhanced strength-to-weight ratio, rigidity, and form retention, which may contribute to the user's perception of improved lightness and ease of use.

The small difference in EMG readings could be due to variations in socket stiffness, alignment, or minor differences in residual limb-socket interface pressure distribution. While not statistically significant in this case, such variations could influence muscle fatigue and gait mechanics over longer durations or across larger populations.

This study supports the broader understanding that material properties in socket design influence not only structural performance but also user satisfaction, which is crucial for optimal rehabilitation outcomes.

CONCLUSION

This case study demonstrates that both thermoplastic and resin-laminated PTBSC sockets offer comparable support in terms of quadriceps muscle activation during prosthetic use in a transtibial amputee. Although EMG data showed no significant difference, the patient reported better comfort and usability with the resin-laminated socket. These findings suggest that socket material selection should not only consider biomechanical factors but also patient-reported outcomes to ensure optimal prosthetic function and satisfaction.

Further studies with a larger sample size and long-term follow-up are recommended to generalize these findings and to better understand the impact of socket materials on neuromuscular function and prosthetic performance.

Declaration by Authors

Acknowledgement: The authors express their heartfelt gratitude to the staff of the National Institute for Locomotor Disabilities (Divyangjan) (NILD), Kolkata, for their invaluable support, guidance, and assistance throughout the duration of this case study. Their dedication and expertise were instrumental in the successful completion of this work.

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Sai Prabha Mishra, Souvik Naskar, Prakash Sahoo, Prasanna Kr Lenka, Ameed Equebal. Comparative analysis of thermoplastic and resin-laminated PTBSC sockets on quadriceps muscle profile in a transtibial amputee: a case study. *International Journal of Science & Healthcare Research.* 2025; 10(3): 92-96. DOI: *https://doi.org/10.52403/ijshr.20250311*

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