COMPOSITE MATERIALS FOR LIMB PROSTETICS LINERS

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Protecting the soft tissues of residual limbs for people with lower amputations is a difficult challenge. In contrast to the plantar tissues of the intact foot, the soft tissues of the residual limb are not used to loads. As a result, the loads transferred to the residual limb by the prosthetic bed can often cause ulcers and other skin problems [1]. This poses a problem, as treatment often involves temporarily discontinuing the use of the prosthesis, which significantly hinders the affected person's ability to carry out daily activities. Lack of comfort when using prostheses, caused by increased heat generation and sweating, are the main problems for amputees, and so far no correlation has been found with the type of prosthesis, the reason for amputation, and the amputated limb [2-4]. The heat inside the prosthetic socket causes sweating, and there have been many complaints about health problems, discomfort, unpleasant odor, and the use of prostheses [3]. Until now, aesthetic and biomechanical properties of prostheses attract the main attention, and prostheses are manufactured without taking into account the problems with heat, sweating, discomfort and cold stress for the patient [4].

Prosthetic liners, the interface between the residual limb and the prosthetic socket, play a critical role in user comfort, suspension, and overall prosthetic function. This overview explores the potential of composite materials in prosthetic liners, delving into their benefits, common types, and future directions. Traditionally, liners were made from rigid materials like thermoplastics (e.g., polyethylene) or elastomeric gels. While these materials offered some level of functionality, they often presented limitations in terms of comfort, adaptability, and long-term use [5].

The emergence of composite materials in prosthetic liners has opened doors to significant advancements in this crucial component. Composite materials, by combining different materials with distinct properties, offer a unique blend of characteristics that address the shortcomings of traditional options [6-8].

Composite liners provide enhanced comfort through improved suspension and moisture management. Thus, they can be engineered to be more flexible and adaptable to the contours of the residual limb. This flexibility reduces pressure points and friction, leading to a more comfortable wearing experience for users, especially during extended periods of activity. Certain composite materials offer superior conformability and can create a more secure seal between the liner and the socket. This enhanced suspension improves prosthetic stability, reducing movement within the socket and providing a more natural feel during gait. Some composite materials possess inherent breathability or can be treated with moisture-wicking technologies. This allows for better sweat and moisture management, reducing skin irritation and promoting overall hygiene [9].

Such qualitative parameters as durability and longevity as well as weight reduction also play a positive role in using composite materials for liners development. Thus, composite materials can be formulated to be more resistant to wear and tear compared to traditional liners [10]. This translates to a longer lifespan for the liner, reducing replacement frequency and overall cost. Moreover, depending on the specific composite materials used, liners can be lighter than their traditional counterparts. This weight reduction can contribute to a more comfortable prosthetic experience and potentially improve energy efficiency during movement.

Prosthetic liners play a pivotal role in ensuring the comfort, suspension, and overall function of prosthetics. These interfaces between the residual limb and the prosthetic socket are crucial for providing a secure fit, minimizing skin irritation, and facilitating natural movement. While traditional prosthetic liners were primarily made from rigid thermoplastics or elastomeric gels, the advent of composite materials has introduced a new era of innovation in this field. For example, silicone and polyurethane are used for liners development. Silicone liners are widely popular due to their exceptional softness, flexibility, and shock-absorbing properties [11]. They provide a comfortable fit against the residual limb, protect against friction, and help reduce the risk of skin wounds or irritation. Combining silicone with nylon or carbon fiber offers superior comfort and durability for sensitive skin. Interestingly, new formulations with shape memory properties are being explored to create liners that adapt to the user's limb shape over time. Polyurethane liners offer remarkable strength and durability. They provide stable support and protection for the residual limb, effectively absorb impacts, and enhance prosthetic stability.

Among other materials could be mentioned thermoplastic elastomer (TPE) and gel materials. Gel liners feature a soft texture and excellent shock-absorbing capabilities. They offer a comfortable fit, protect against friction, and help distribute pressure evenly. Recently, hydrogels were tested as promising materials for liners. These water-based materials offer exceptional conformability and can be infused with medications or antimicrobial agents for added benefits. TPE material combines the properties of rubber and plastic, resulting in a liner that is flexible, comfortable, and shock-absorbing. It also adheres well to the skin and provides protection against friction [12]. Blending thermoplastics with elastomeric materials like polyurethane creates liners that are both flexible and supportive. What is even more important, targeted pressure relief zones can be incorporated through specific material combinations for areas prone to discomfort with the use of such kind materials.

Despite the wide range of materials prosthetic liners can cause skin irritation, increased sweating (leading to bacteria growth and odor), and wear and tear due to friction. Additionally, instability of the liner can occur. In this context, there is a need to personalize the choice of liner material for limb prosthetics. The choice of the correct liner depends on the level of activity and needs of the users, as well as on the suspension system of the prosthetic leg [6]. Although liners provide comfort to wearers, discomfort occurs due to perspiration and insufficient evaporation.

Prosthetic socket and liner design must not only facilitate proper patient gait but also meet comfort requirements for the wearer [4]. Consequently, addressing these demands necessitates consideration of both the structural design of the prosthetic socket and liner as well as the mechanical and surface properties of the materials used.

Developing an effective cooling solution presents a complex challenge. Heat removal from the limb-socket interface can involve convection, radiation, evaporation, and conduction; however, each of these mechanisms can vary within the prosthetic socket environment. Recent advancements in prosthetic sockets and materials are gradually addressing this issue. Promising approaches include both incorporating cooling channels into prosthetic sockets and combining phase change materials (PCMs) with liners. The first one allows for direct heat transfer from the residual limb to the external environment. And PCMs can absorb and release heat, maintaining a narrow temperature range for the patient's limb [12].

The potential advantage of each of these approaches lies in their ability to maintain skin temperature below a certain threshold. A cooled socket, in turn, can extend the effective lifespan of the PCM liner under prolonged elevated residual limb temperatures [13]. Future prospects in liners development with composite materials are focused on materials beyond traditional, like alloys with shape memory properties. This approach could potentially create liners that automatically adjust to the user's limb shape and activity level. Biocompatible polymers are being developed to minimize the risk of allergic reactions and promote skin health. Besides, material advancements are not solely focused on comfort. There is a need to develop liners with specific functionalities. For example, materials with varying degrees of friction can be strategically placed within the liner to improve socket suspension and prevent movement within the socket. Embedding sensors into the liner material allows for real-time monitoring of pressure distribution, temperature, and even sweat levels. This data can be used to personalize prosthetic adjustments and optimize liner performance.

Conclusions. Optimizing the material composition of prosthetic liners requires a comprehensive approach that considers both mechanical and surface properties. By incorporating cooling solutions and advanced materials, researchers are paving the way for more comfortable, functional, and durable prosthetic liners.

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