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BREATHABLE LINER FOR TRANSRADIAL PROSTHESES

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ABSTRACT

The socket as the link between residual limb and prosthetic components is the crucial part of the prosthesis influencing the amputee's acceptance considerably.

In addition to protection from outside influences, the skin is responsible for regulating the body temperature. As parts of the skin are missing due to amputation, this functionality is minimized. This effect is increased by common liners consisting of silicone or equivalent materials, covering the residual limb surface.

A new developed liner is made of spacer fabric in combination with partial silicon coating for suspension. This way the functionality of the skin inside the socket is supported to regulate temperature based on permeability to gas and humidity. The cushioning effect of the liner reduces pressure peaks and shear forces to prevent skin breakdown.

The new approach of an interface design combines the comfort of using the conventional liner technique with the support provided by natural skin functionality.

INTRODUCTION

The skin of an adult person covers an area of approx. 1.6 - 1.8 m². [1] It is the largest human organ and a protective shield at the same time. The skin serves as respiratory, metabolic and protective organ. In addition, the skin supports the control of the body temperature. This is done in different ways. The release of heat by thermal conduction depends on the surrounding material. As humans prefer materials with low heat conductivity, loss of heat is low in this way. Heat release by convection and radiation is more effective and dependent on the difference of the temperature between body and environment. The dermis includes sweat glands. The sweat produced there is excreted by the pores of the epidermis located above. Due to evaporative cooling, the body temperature is effectively regulated independent of the ambient temperature. This requires that the sweat may evaporate which depends on the difference of the partial pressure of water vapour on the skin and in the air. Heat is transported away, even if the ambient temperature is higher than that of the skin which blocks other channels of heat release. As the limbs occupy more than half of the body surface, they also release more than half of the heat. [2] With the amputation of a limb, a large part of the body surface gets lost. The remaining part of the skin reacts with increased perspiration to balance the body temperature. [3, 4] In addition, the skin of the residual limb is covered by the prosthetic socket.

LINER

Liners have various tasks in prosthetics. They control disturbing forces and increase the wearing comfort of the whole prosthesis. In contrast to sockets without liner, the material properties of liners provide for enhanced suspension of the residual limb. In addition, donning is easier and more comfortable when a liner is used. Taking the plaster cast is facilitated; the handling for the patient is improved. Liners of silicone, polyurethane (PU) or copolymers (TPE) have become the fitting standard in the markets. Silicone has low elasticity and is breathable. PU absorbs humidity. Copolymers have high elasticity. These variants have in common that sweat cannot evaporate. In this way the liner inhibits the intended cooling process of the skin. In a survey conducted by van de Weg [5], patients report about the following three major problems that arise when wearing different liners. 26 % of the patients complain about perspiration when a liner is worn. 22.8 % have pains and 19.9 % mention problems with respect to unpleasant odour generation. It has to be pointed out that this study deals with prosthetic fitting of lower limbs. As the mechanical load situation is different there, the statements on pain development cannot be directly associated with prosthetic fitting of upper limbs. Perspiration and undesired odours, however, may develop with upper limbs too. Mak [6] describes that temperature and increased sweat production have negative effects for the patient.

Present liners are usually connected to the prosthetic socket by distal closure systems. This may lead to a "milking effect" as loading of the residual limb concentrates in the distal connection elongating the liner and the residual limb. Another, non-distal connection between socket and liner could improve the wearing comfort. [7]

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RESULTS

Textile

For a new liner concept, a special 3-dimensional textile spacer fabric has been developed. The side facing the skin is provided with bacteriostatic fibres that include silver ions (Ag+). The antimicrobial substance does not migrate into the environment. [8] The ions prevent the bacteria from multiplying [9] resulting in reduced development of unpleasant odours. The middle layer of the textile is provided with monofil threads forming a distance with damping function between bottom and cover layer. This effect is used for medical seat and bed padding to prevent pressure sores or for insoles [10, 11]. The monofil threads are provided with multifil fibres lying in-between. Due to their large surface, these Coolmax® fibres transport the moisture to the outside. The breathability of the textile is not impaired even in case of high humidity. On the side facing away from the skin the textile surface is provided with microfibres. Due to the large surface, these fibres have good capillary effects allowing for effective sweat evaporation.

New liner

The whole material includes a large air layer providing for low heat conductivity comparable to foam of approx. λ_{Sf} = 0.04 W/mK (table 1). Due to the temperature-isolating characteristics, only little heat is removed from the skin (convection is suppressed) so that the liner (figure 1) is perceived as pleasantly warm [10]. The low coefficient of static friction of the textile does not allow for the required suspension on the skin. This is compensated by partial silicone coating whereas the climatic effect is hardly limited. Produced sweat that may considerably reduce the static friction is transported away. The main objective is to create a functional combination of breathability and suspension of the liner on the residual limb.

Table 1: Examples for heat conductivity [12]

Material	Heat conductivity λ [W/mK]
Steel	45.0
Water	0.6
Silicone	0.2
Polyurethane	0.19
TPE	0.18
Spacer fabric, Foam	0.04
Air	0.0026

The circumferential elasticity of the liner is high. The liner is offered in different sizes to meet the individual needs of the patients. The longitudinal elasticity is very low. In case of tensile loads, shear stress on the skin is minimized. A distal pin has been consciously avoided. Force transmission is distributed to the whole liner. The space for the distal attachment mechanism is not required any longer. The liner may be simply cut to the needed length. Compared to common liners, the textile liner offers increased compressibility resulting in more physiological movements of residual limb and muscles. The optimized textile allows shortening without post-processing. Hygiene aspects have been realized in that way that the liner is easily washable.

Figure 1: Current functional model of the breathable liner

Patient trial

In a patient trial the individualization of the liner was conducted by simply cutting it to the right length. Due to the right elasticity of the material the liner provided a comfortable result for the patient in relation to compression and cushioning effect. In our case the patient had a distal bony residual limb (figure 2).

Socket

The arm liner becomes useable only in combination with an appropriately adapted prosthetic socket. The inner

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sockets of traditional transradial prostheses are made of deep-drawn thermoplastic, which provides both an intimate fit with the residual limb and sufficient strength necessary to support the terminal device. In practice, the shape of the socket is often difficult to control, resulting in a less-than-optimal fit. Moreover, a completely closed construction may lead to donning, doffing and perspiration issues. A prosthetic socket with an open external frame has been developed to allow for easier donning and doffing, adjustment to variations in arm circumference. The socket along with the breathable liner could offer improved ventilation. An intimate fit is offered by a combination of residual limb-supporting flexible parts and the liner. The intention of the socket-design is to support the CPO for flexible and effective fitting of the residual limb.

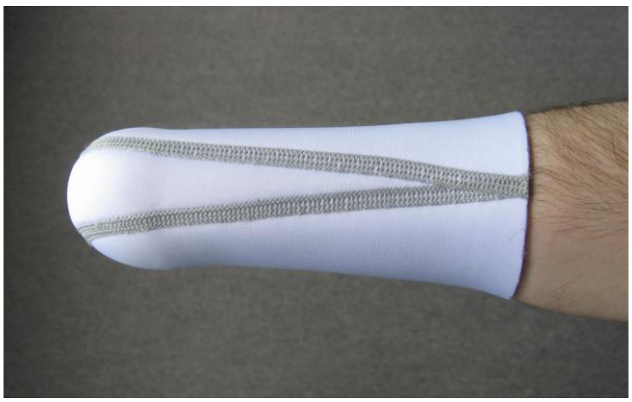

Figure 2: Individualized liner in patient trial

CONCLUSION

In contrast to existing systems, the new arm liner ensures the breathability of the skin. Humidity is transported to the outside to evaporate there. Undesired odours are reduced increasing the wearing comfort. So far the effects have been confirmed by a case study. The anatomic, large-surface attachment of the socket to the liner shall resolve the present problems of distal connections (milking effect, local loading, etc.). To confirm these effects in practice, further investigations including patient tests are required.

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