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Case report

A newly developed socket design for a knee disarticulation amputee who is an active athlete

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Abstract

This case report describes a newly developed socket design for a world class knee disarticulation athlete. To meet the demands concerning especially the suspension of the prosthesis a new type of socket was developed. The socket is made from carbon fibres and polyaramid fibres and is designed with a slit in the socket creating a flexible flap. This allows the amputee to both increase and decrease the inner circumference of the socket, thereby allowing the amputee to adjust the socket to stump variations.

According to the amputee the new design offers an excellent fit and enables him to concentrate fully on the technical aspects of the different disciplines.

Introduction

Many young amputees are top-level athletes and they therefore make heavy demands concerning the fit, function and suspension of their prostheses.

Because components such as prosthetic knee joints and prosthetic feet have reached high development and functional levels and because the components are commercially available for all athletes it has become increasingly important to optimise the stump/socket interaction – especially with regard to the suspension and control of the prosthesis and the transmission of force from stump to socket during sports activities. Stump/socket interaction is also important to optimise in order to relieve the intact limb since Nolan and Lees (2000) have demonstrated that the loading of the intact limb is increased even in normal walking.

The knee disarticulation stump is bulbous shaped and the socket therefore often has to be equipped with a double wall soft socket or functional windows to facilitate the mounting of the prosthesis (Wilde and Baumgartner, 2000; Lyquist, 1983). Both solutions are fully acceptable in normal everyday life but for activities such as sprinting, jumping, and javelin throwing these solutions do not offer the best possible suspension and the amputee often has to use different types of harness to get a satisfactory suspension.

Always present is the inevitable problem of variations in stump volume which affect the suspension. Furthermore, the amputee normally uses the same prosthesis over a relatively long period of time. Many amputees experience stump variation problems even many years after the amputation.

This article presents a case report of a newly developed knee disarticulation socket design where all the above problems have been solved in an easy and functional manner for an active athlete.

Background

In 1985, at age 14, the young man was amputated at knee disarticulation level because of a right-sided crus sarcoma. He started running when he was 23 and over the years he has had many different prosthetic knee joints and feet but he has always had a socket with a double wall soft socket.

Today he is an international top level athlete. At this level most athletes train every day and the

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physical and technical capacities are therefore comparable between athletes. The construction of the prosthesis can thus be of vital importance for success because prosthetic suspension and control are some of the main factors in the athletes' endeavours to win competitions.

The authors have previously tried to solve the suspension problems by using different types of harnesses but without being able to completely solve the problems with pistoning and unsatisfactory prosthetic control. There have also been inconveniences from the harness in the form of abrasions etc. due to very high loads during sports activities.

At times there have also been changes in the amputee's weight which have influenced the size of the stump and made it difficult to maintain an optimal suspension. It has therefore been necessary to adjust the prosthesis numerous times over a short period of time.

Since the authors did not find acceptable solutions to the above problems in literature they started a new development co-operation with the amputee in order to find a simple and efficient solution to the suspension and control problems.

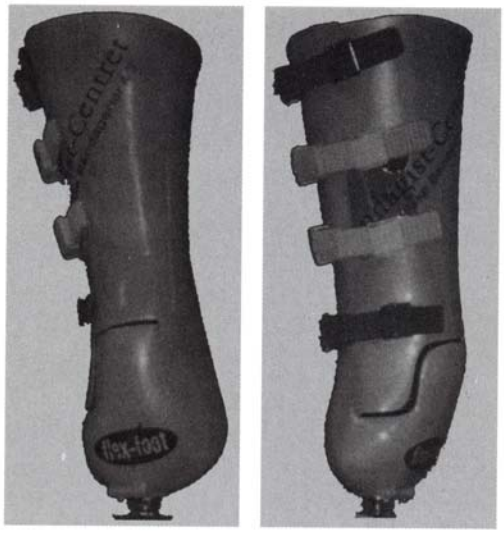
Demands concerning the construction of the socket

The conclusion was reached that the most functional solution would be a socket where it is possible to make minor as well as major adjustments by increasing or decreasing the inner circumference. This would give the best possible suspension and transmission of force between stump and socket - even with large changes in stump volume. It should also be possible for the athlete to adjust the socket from top to bottom and it should be easy to don and doff.

Furthermore, the socket should be light in order to optimise the athlete's performance, but at the same time strong enough not to compromise the strength needed during the sports activities

Development result

To satisfy all demands concerning the suspension of the prosthesis it was decided to have a lateral slit in the socket going from the top and down to 70mm above the bottom, then turning anteriorly and continuing proximally across the patella until it ends anteromedially. The result is an adjustable flap which covers the socket like a rolled up sheet of paper (Fig. 1).



(a) (b)

Fig. 1 Adjustable flap a) Anterior view b) lateral view

This makes it possible to adjust the volume of the socket and ensure a tight suspension of the prosthesis during sports activities even if the stump volume changes. To obtain a safe and flexible closure the adjustable buckle system

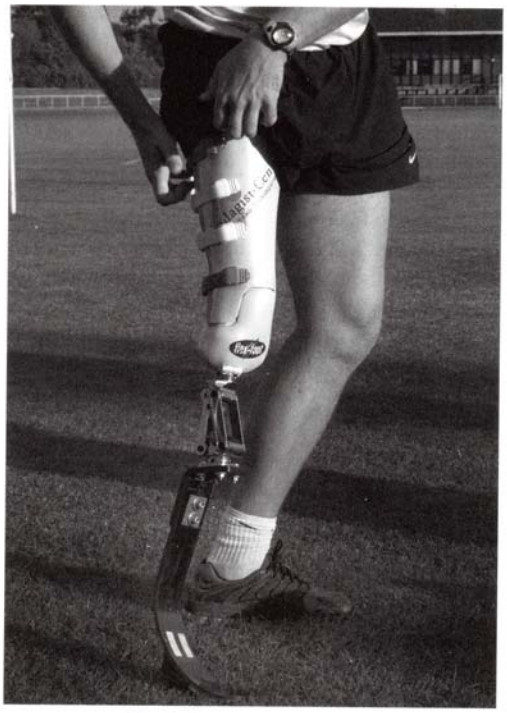


Fig. 2 Securing the closure

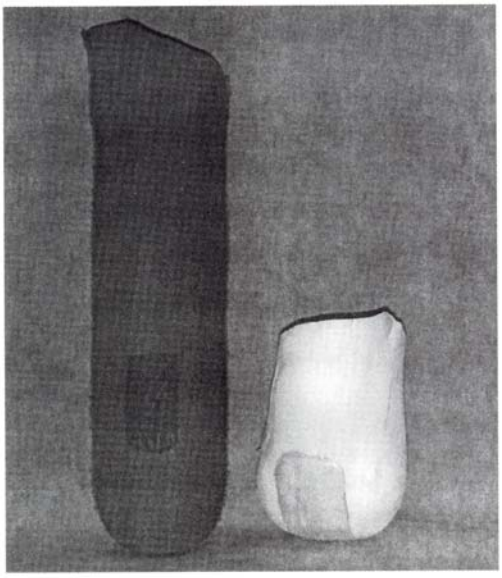


Fig. 3 Soft socket and liner.

known from ski boots was used which permits the fit to be adjusted at all times (Fig. 2).

The material used for the socket is carbon fibre in an epoxy matrix (prepreg) which combines low weight and high strength. To make the flap flexible the authors have used woven polyaramid fibres (Kevlar®) also in an epoxy matrix (prepreg). Polyaramid fibres are elastic and very strong and they do not break despite continuous deformations (Peters, 1998).

Because the amputee's patella is very sensitive to pressure the authors have used an approximately 100mm long and 3mm thick soft socket made from closed-cell polyethylene foam mounted on a Luxury liner® which has been rolled onto the stump (Fig. 3). This combination gives a good pressure distribution when the socket is tightened and at the same time it protects the distal bony structures of the stump.

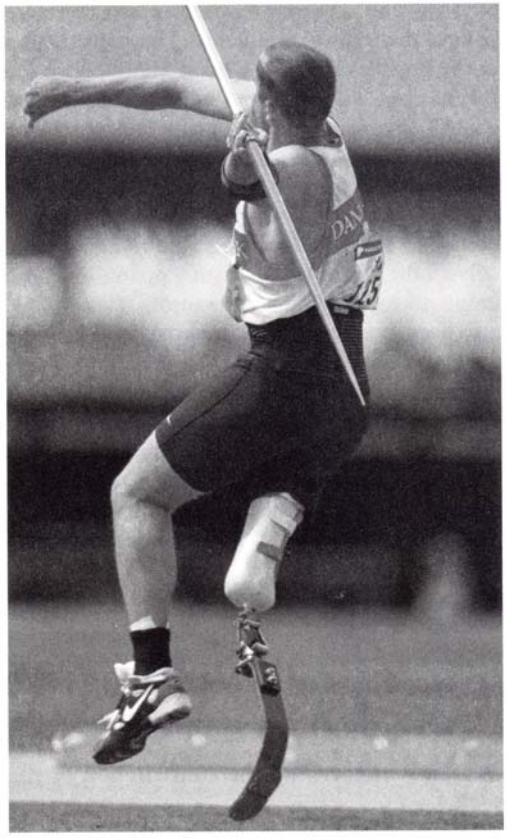


Fig. 4. The socket in use.

Results and athlete's opinion

The socket has a mass of 0.940kg without buckles and adapter. Socket flexibility is shown in Table 1. This table shows that it is possible to change the internal circumference by approximately 14% everywhere on the socket. This gives optimum prosthesis suspension despite varying stump volume.

After the amputee got the new prosthesis he improved his 100m time by 0.38 second and

Table 1. Change in internal circumference at three different positions in the socket.

	Socket in neutral position mm	Max. closed usable socket mm	Max. usable opening in socket mm	Total change max. min. %
100mm from top of socket	385	360	410	13.9
180mm from top of socket	315	290	340	17
260mm from top of socket	290	285	325	14

added 0.50m to his long jump. Furthermore, he won a gold medal in the javelin throw and a silver medal in the pentathlon at the recent Paralympics in Sydney, Australia. Here he also improved his personal record in javelin throw by 8 metres and set a world record of 52.74 metres in group F42 i.e. amputees with a unilateral knee disarticulation or trans-femoral amputation competing in the field (Fig. 4).

The athlete experiences a marked improvement in suspension compared to his previous sockets which also had a good fit but were unadjustable. Because the new socket can be adjusted according to volume changes of his stump he now has more freedom to concentrate fully on the technical aspects of the different disciplines.

The strongly improved prosthetic suspension has optimised the control of his prosthetic knee joint and the transmission of force from stump to prosthesis. According to the amputee this is clearly the most important advantage of the new socket.

Conclusion

The authors believe they have fully met the demands concerning the socket. The prosthesis is easy to don and doff and the amputee can tighten the socket to the stump and adjust the pressure without experiencing any pistoning between stump and socket even when the stump volume has changed. The authors of this article have not seen other knee disarticulation prostheses with similar possibilities for increasing or decreasing the internal circumference of the same socket.

The system also makes a well-functioning first-time prosthesis for a knee disarticulation amputee whose stump volume will most likely change a lot within a short period of time.

The described socket construction could also be used for active Symes amputees because their stumps also have a bulbous shape and because they often experience the same suspension problems as knee disarticulation amputees.

REFERENCES

LYQUIST E. (1983). Casting the through-knee stump. *Prosthet Orthot Int* **7**, 104-106.

NOLAN L, LEES A. (2000). The functional demands on the intact limb during walking for active trans-femoral and trans-tibial amputees. *Prosthet Orthot Int* **24**, 117-125.

PETERS ST (1998) Handbook of composites./2nd edition. – London: Chapman & Hall

WILDE B., BAUMGARTNER R. (2000). Physiotherapie und Sport nach amputationen. – Stuttgart: Georg Thieme