The Jaipur foot

A. P. Arya, L. Klenerman

The Jaipur foot was developed for barefoot amputees by Professor P. K. Sethi. He used local artisans and readily available materials. The prosthesis was cheap and could be made in one hour. It enabled amputees to work in rural conditions, muddy and wet fields and to climb trees. It has been widely used in India, South East Asia and Africa, where local variations to the design have now been made.

The number of amputees worldwide has risen alarmingly as a result of the increasing and indiscriminate use of antipersonnel land mines which have been sown in enormous numbers in rural areas. Even after the cessation of fighting, fresh injuries occur from the delayed detonation of these weapons.1 The most likely injury is a traumatic amputation of the foot or leg.2 Rehabilitation of the amputees in countries where the majority of the populace have a low-income has several major constraints, the foremost being the availability of an affordable prosthesis suitable for their lifestyle. The development of the Jaipur prosthetic foot in the early 1970s has been a major contribution.

Professor P. K. Sethi was Foundation Professor of Orthopaedics at the Sawai Man Singh (SMS) Medical College and Hospital, Jaipur, India. He observed that lower-limb amputees preferred to use crutches rather than prostheses fitted with a Solid Ankle Cushion Heel foot (SACH). This prosthesis was unsuitable for the demands of a ‘floor-sitting’ lifestyle in a warm country such as India which were different from those of the ‘chair-sitting’ habits of the cold countries of Europe. Limbs made of polymer with a rigid terminal device such as the SACH foot did not allow the amputees to sit on the floor, squat, walk barefoot or work in muddy, wet fields, and they broke easily. There was an obvious need for a prosthesis suitable for Indian amputees.

Sethi’s first efforts were to modify the SACH foot. Its solid wooden keel did not allow any movement and therefore a wedge was removed in order to allow dorsiflexion. This produced limited movement and resulted in the removal of increasingly larger wedges until almost nothing was left of the proximal section of the keel. At this stage he abandoned the SACH foot and introduced a completely new design.

This prosthesis, which he named the ‘Jaipur Foot’, consisted of three separate blocks, one of micro-cellular rubber for the hind foot and the other two of laminated wood for the ankle and forefoot, appropriately shaped and wrapped by an inner layer of tyre cord rubber and an outer layer of skin-coloured soft rubber, with tough rubber for the sole. The foot was then vulcanised in an aluminium die to look life-like. The forefoot wooden block was later replaced with a rubber block, similar to that of the hindfoot in order to provide pronation and supination, and to allow stability on uneven ground (Fig. 1). The foot was attached to an aluminium socket covered with stockinette, glued, water-proofed and individually painted in the appropriate skin colour.

The large sponge rubber block at the hind foot acted as a universal joint, capable of providing multidirectional movements including dorsi- and plantar flexion, inversion, eversion, adduction and abduction. The foot could rotate on the leg. This allowed the amputee not only to squat and sit cross-legged, but also to walk comfortably on uneven terrain, since the foot could adapt easily to the underlying surface (Fig. 2). Being waterproof, it could be used in mud and water. Its normal appearance was a great advantage since it did not need a shoe and amputees could walk barefoot, which followed the custom of not bringing shoes into kitchens or places of worship. The foot was sturdy and tough and could withstand the stresses of everyday use.3,4 Amputees felt very secure with these feet and they required little gait training. This was thought to be due to the large area of support. The prosthesis could be tailor-made in front of the user in less than an hour and cost approximately 250 Indian rupees (£3.00).5
Sethi first presented his work in Europe in 1971. He did not patent the foot in spite of pressure to do so, since he believed that commercialisation would take it out of reach of those who needed it most. The foot was so simple to make that it could be produced in any village with an artisan. Because of this novel approach, millions of Jaipur feet were made locally and fitted to amputees in India, Pakistan, Sri Lanka, Bangladesh, Vietnam, Cambodia, Afghanistan and several African countries. By March 2003 a single non-government organisation, Bhagwan Mahaveer Viklang Sahayata Samiti, had provided 690 480 limbs in India and 15 169 in 19 other countries. Lives were transformed since amputees were made physically and economically independent.

A comparative study of the SACH, Seattle (one of the first energy-storing feet in which the forefoot keel was designed to store energy as a cantilever beam and then return this stored energy during push off) and the Jaipur foot was carried out to compare their biomechanical properties by measuring ground reaction forces. Three transtibial amputees participated. Each was provided with an experimental limb adapted to accommodate the three prosthetic feet. The normal foot was used as a control and all wore their usual limb during control trials. The ground reaction force was measured using a Kistler force plate (5281B, Kistler Instruments Inc. Amherst, New York), which measured six variables from the vertical and anteroposterior components of ground reaction forces. The normal foot generated significantly larger ground reaction forces than the prosthetic foot. The capacity for shock absorption of the SACH foot was best, but with the Jaipur foot the anteroposterior braking impulse, which represented the force of loading, was significantly larger and nearer the value for the normal foot. This implied that amputees placed more load on it because they felt secure and confident.

The main disadvantage of the Jaipur foot was its weight. It was heavier than most other prosthetic feet and had not been standardised. These two factors mitigated against its use in the Western world.

Despite extensive use for many years, it is only recently that the International Society for Prosthetics and Orthotics, has carried out field trials of the Jaipur foot to assess its durability and performance. Jensen and Raab used 81 Jaipur feet from two private manufacturers in India and tested them on established amputees at the International Red Cross Committee project in Ho Chi Minh City in Vietnam for a mean of 16 (8 to 17) months. All the amputees were active users who walked for distances exceeding 1 km and had a median daily use of 14 hours. The authors reported that compliance was high and that nearly all the users were satisfied. At the end of the study 27% of the feet had failed and needed exchanging mostly because of fracture of the skin and gliding between the sponge rubber layers of the heel block. It was felt that since the Jaipur foot was constructed for lightweight Indians, there was a risk of premature breakdown when used by heavier persons. This, combined with its manufacture by relatively untrained artisans, was thought to place it at a disadvantage when used extensively in the developing world.
The Jaipur foot can be used with any superstructure of the leg and thigh. The original design by Professor Sethi was made from aluminium sheets. These have been replaced largely by high-density polyethylene. Jensen et al. reviewed 172 amputees using this type of prosthesis in projects in Honduras, Uganda and India after a median of 35 months. Craftsmanship and fit were assessed as poor in 56%. Although there was patient satisfaction in 85% and a compliance rate of 94%, the high-density polyethylene-Jaipur foot transtibial system was not considered to be acceptable, since 49% of users reported walking distances of less than 1 km and 36% experienced discomfort. The major effect on outcome was the poor education and training of the artisans involved. In this respect, Professor Sethi’s decision not to patent and standardise the Jaipur foot has proved to be a double-edged sword; although millions of feet have been made, the quality of production and fitting has been inconsistent.

The concept of the vulcanised rubber foot has become popular and different variations have been introduced. Jensen and Treichi tested 21 different prosthetic feet, of which 14 were made from vulcanised natural rubber or foam rubber, produced in many different countries including Vietnam, Cambodia, Angola and Tanzania.

The Jaipur foot demonstrates the philosophy of using locally-available material and resources to find solutions to challenging problems in the developing world. An analogy can be drawn with the development of the Ilizarov system, which revolutionised limb reconstruction. The use of local materials with which craftsmen are familiar has several advantages in that costs can be kept down and, provided that there is adequate and close supervision, existing craftsmen can quickly be trained as limb-makers. These advantages are relevant in areas where funding is scarce and there is a reservoir of practical and industrious manual workers.

We wish to acknowledge the invaluable help we received from Dr S. Jensen of the International Society for Prosthetics and Orthotics, Copenhagen, Denmark. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References