

The TC double socket above-knee prosthesis

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Abstract

The conventional total contact suction AK prosthesis presents several disadvantages, such as difficulty in wearing the socket in a sitting position, difficulty in obtaining a favourable disposition of the stump soft tissues in the socket and difficulty in avoiding stump perspiration problems. In an attempt to solve these disadvantages, a new AK prosthesis with a thermoplastic double socket was developed at the Tokyo Metropolitan Rehabilitation Center for the Physically and Mentally Handicapped. The double socket is composed of an external socket attached to the lower parts and a detachable internal socket, and appears to solve all the disadvantages of the conventional prosthesis. This prosthesis is called the TC prosthesis, an abbreviation for the Tokyo Metropolitan Rehabilitation Center. The first model of this prosthesis, (TC-1) has a metal valve. A new rubber sheet valve was developed to solve several disadvantages of the metal valve in the TC-2 prosthesis. Since November 1978 the TC-1 has been fitted to 295 AK amputees, including 9 bilateral AK amputees, and since March 1980, 145 AK amputees have received the TC-2, including 6 bilateral amputees. Satisfactory results have been obtained with both prostheses.

Introduction

Since the suction socket AK prosthesis was first patented by Dubois Parmelee of New York in 1863, improvements have resulted from the contributions by specialists in various countries. A practical suction socket was developed in Germany at the beginning of World War II, however, use of this prosthesis was limited to

Germany until the end of the war. Since 1945 use of the suction socket has spread throughout the world (Thorndike, 1949). Although the suction socket AK prosthesis did not need additional suspension aids, it led to stump oedema caused by the negative pressure in the interspace between the stump and the socket. To solve this problem, the total contact suction socket was developed by Kuhn in 1962.

The value of the modern total contact suction socket is well-known throughout the world. However, the total contact suction socket still has the following disadvantages:

1. difficulty in wearing the socket in a sitting position
2. difficulty in obtaining a favourable disposition of the stump soft tissues in the socket
3. difficulty in avoiding stump perspiration problems
4. difficulty in modifying the socket shape according to the changes of the stump circumference
5. difficulty in obtaining a comfortable fit
6. weight

Many improvements have been made to overcome these disadvantages. For instance, Sinclair (1969) devised a new double socket suction prosthesis which was composed of a rigid polyester socket with various cut-outs and a detachable flexible silicon liner socket. It was hoped that geriatric amputees with heart disease could wear this prosthesis in a sitting position, but it did not work as well as had been hoped. A thermoplastic double socket prosthesis for bathing is produced by the Otto Bock Company. The double socket cannot be separated and has no substantial changes from the ordinary prosthesis.

A transparent polycarbonate socket was introduced by Mooney (1972) and a lightweight adjustable socket was developed by Irons (1977). However, an improved prosthesis which

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solves all the disadvantages described above has yet to appear.

The TC-1 prosthesis

Since the disadvantages listed above are caused mainly by the properties of the socket itself, a new AK prosthesis was devised with a double socket. This new type of AK prosthesis is called the TC-1 (Fig. 1 left), an abbreviation for the Tokyo Metropolitan Rehabilitation Center Type-1 (Koike, 1979).

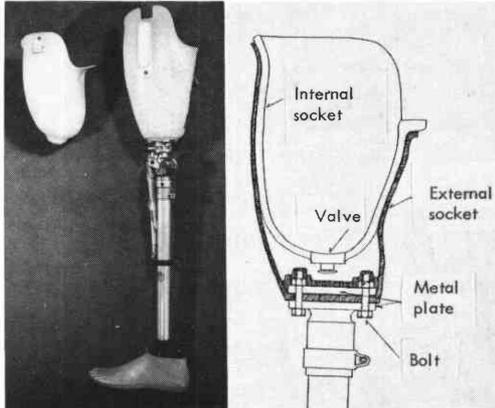


Fig. 1. Left, the TC-1 prosthesis. Right, section through the double socket.

Structure, materials and manufacturing procedures

The double socket is composed of both an internal and an external socket. The external socket is attached directly to the metal plate on top of the lower part of the prosthesis by four bolts without using a wooden block as is normally used in the conventional total contact suction prosthesis (Fig. 1 right). The external socket is constructed to have enough area to maintain sufficient contact with the internal socket and also to have enough space to hold the perspiration coming down through the valve of the internal socket.

The metal screw valve is attached at the bottom central portion of the internal socket (Fig. 2, top).

The two sockets (Fig. 2, bottom) can be attached and detached quite easily by means of a Velcro strap at the outer lateral wall of the external socket pulled through a "D" ring at the lateral upper edge of the internal socket. A low density polyethylene sheet is used for the internal socket and a low density polypropylene sheet is used for the external socket. To

manufacture the internal socket a polyethylene sheet, 500 mm square and 10 mm thick, is softened in an oven and then draped over a prepared positive model. It is moulded over the cast by means of vacuum-forming (Wilson, 1974). To make the external socket a polypropylene sheet, 500 mm square 3 mm thick, is softened by heat and then placed cylindrically around the internal socket after an appropriate amount of plaster has been placed over its bottom part. It is welded at both ends (Donaldson, 1977). The thickness of the polypropylene sheet can be changed according to the amputee's weight. A middle density polyethylene sheet can also be used to simplify the welding process.

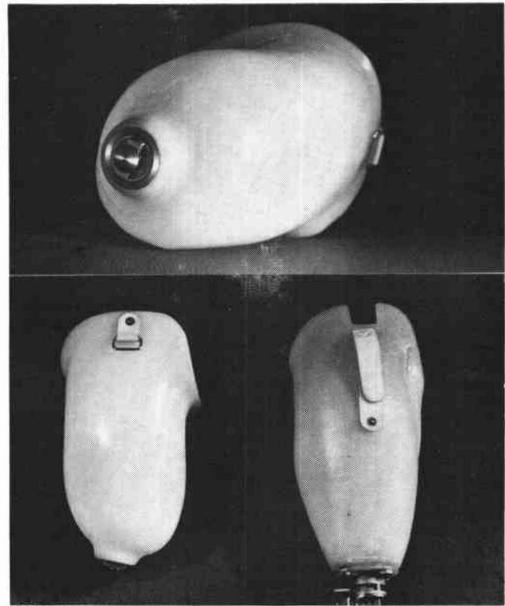


Fig. 2. Top, position of the valve. Bottom, internal socket with D ring and external socket with Velcro strap.

Advantages of the TC-1 prosthesis:

1. Because of the reduced weight and ease in handling the internal socket, donning is easy in a standing or sitting position (Fig. 3, left). The wearer can easily insert his stump into the internal socket and then into the external socket in one pushing motion (Fig. 3, right). Donning the TC-1 is completed by attaching both sockets together with the Velcro strap. Wearers of the conventional

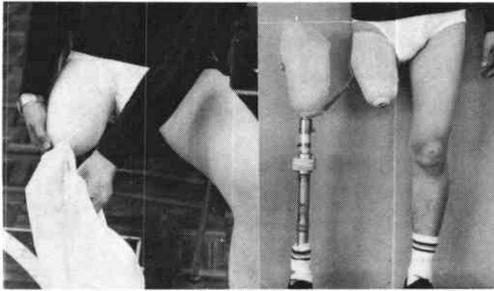


Fig. 3. Left, donning the internal socket in a sitting position. Right, the internal socket in position prior to donning the complete prosthesis.

total contact AK prosthesis frequently experience the socket slipping off the stump while in a sitting position because the suction cannot be maintained. However, with the TC-1, flexibility of the internal socket allows the stump to maintain close contact with the socket at all times. The external socket can be shifted while sitting for long periods, hence sitting tolerance is markedly increased. The internal socket is also used as a stump shrinker while the wearer is sleeping.

2. Distortion of the remaining muscles and other soft tissues, which could be the cause of abnormal gait patterns, is prevented in the TC-1 because the valve is set at the bottom central portion of the internal socket. This provides a favourable disposition of all the soft tissues along the socket axis and ease in pulling out the cloth from the stump.
3. Slipping off during the swing phase, sweat stains on clothing, and problems hindering the proper functioning of the knee joint mechanism due to perspiration are solved to a great degree by the double socket system and the position of the valve with the TC-1.
4. Changes in contour and circumference of the stump are easily accommodated as the shapes of both sockets can be modified easily with heat application even in a training room. The same prosthesis can be used therefore, from the first day until the last day of the training programme.
5. Wearing the TC-1 is comfortable because pressure between the stump and the well-

contoured and flexible sockets of the TC-1 is equally distributed.

6. Adequate contact area of the stump to the internal socket and adequate contact area between the two sockets can be observed through the semi-transparent materials of the sockets without an X-ray examination.
7. The cost of the prosthesis is reasonable because the manufacturing procedures are not complicated and mass production of the sockets is possible.

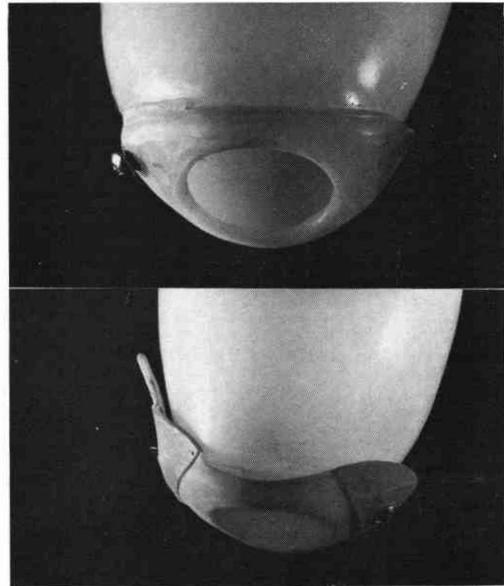


Fig. 4. Top thermoplastic base with valve hole of the TC-2 prosthesis. Bottom, the rubber sheet valve.

The TC-2 prosthesis

The metal valves of the TC-1 are not without some problems. Sometimes injury to the stump skin occurs while screwing the valve into the socket. At other times there is difficulty in maintaining total contact when a bony protrusion exists on the end of the stump. The valve's thickness can also create problems at times. In an attempt to solve these problems a new rubber sheet valve was developed. The thermoplastic base containing the valve hole is welded to the bottom central portion of the internal socket (Fig. 4, top). The valve hole is then covered by a thin sheet of rubber which is held in place by a screw on the posterior side and

a hook on the anterior side (Fig. 4, bottom). The prosthesis using this new rubber sheet valve is known as the TC-2.

Advantages of the TC-2 prosthesis

1. As the rubber sheet valve does not have a metal base, the dimensions of the valve hole can be made larger than those of the metal valve (Fig. 5, top). Consequently, pulling out the cloth from the stump and allowing the perspiration to leave the internal socket become much easier.
2. The thickness of the rubber sheet valve is less than $\frac{1}{3}$ of that of the metal valve (Fig. 5, bottom) so lowering the knee joint can be minimized in the case of knee disarticulation.
3. The shape of the valve hole can be changed according to the condition of each stump (Fig. 6, top).
4. Since this valve does not cause pain, total contact between the stump and the socket can be maintained even in cases with bony protrusions (Fig. 6, bottom).
5. The rubber sheet valve does not injure the stump skin and can be easily attached.
6. The TC-2 is much more comfortable to wear (Fig. 7).

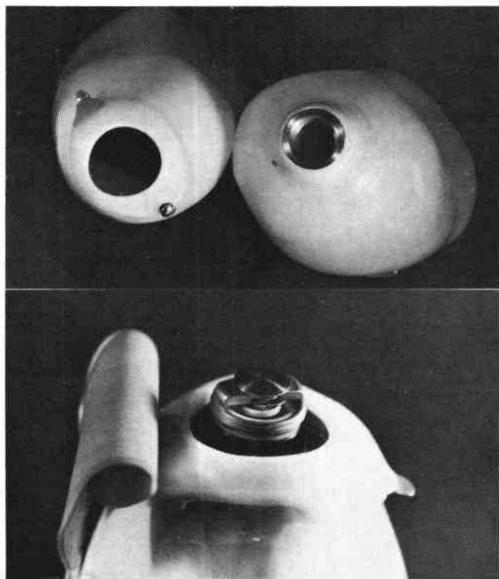


Fig. 5. Top, the TC-2 valve hole can be made larger than that for the metal valve. Bottom, the rubber sheet valve is $\frac{1}{3}$ the thickness of the metal valve.

7. The cost of the rubber sheet valve is far less than the metal valve.

Discussion

Various disadvantages of the conventional total contact suction prosthesis are caused mainly by the hard single socket made of thermosetting plastics or wood. Great efforts have been continuously made to solve the disadvantages by many in the medical profession.

A new total contact suction socket was devised by Sinclair (1969). This prosthesis was composed of a rigid socket with variously located cutouts and a detachable flexible liner socket. The liner socket was made of RTV silicon and the valve was located at the same position as the ordinary socket. Although this prosthesis was aimed at making it possible for geriatric AK amputees with heart disease to wear the suction socket in a sitting position, it resulted in failure. This failure might have been caused by the excessive flexibility of the detachable liner socket and the position of the valve.

A double socket AK prosthesis made of polymethylmethacrylate is produced for bathing by the Otto Bock Company. All components

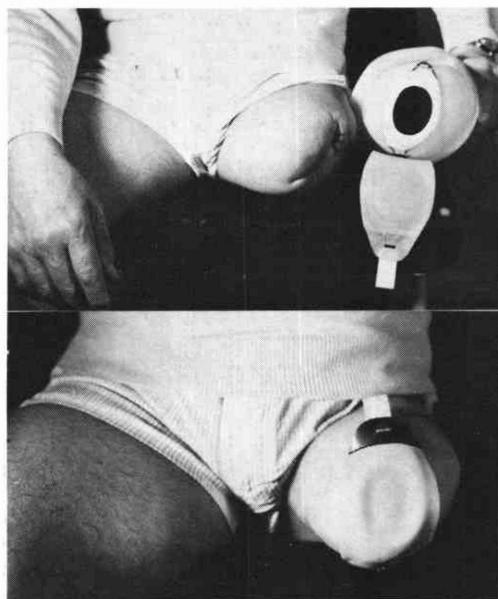


Fig. 6. Top, the shape of the valve hole may be altered to accommodate the stump condition. Bottom, TC-2 internal socket shown on amputee.



Fig. 7. The prosthesis in use.

except the foot of this prosthesis, including the knee joint, are fabricated in polymethylmethacrylate. The internal socket cannot be removed from the prosthesis and is rigid. While the wearer of this prosthesis can stand in a pool or shower room, the prosthesis cannot withstand the heavy duty required for daily living. The socket can be modified partially with heat application but cannot be modified over the entire socket surface to accommodate a greatly changed circumference of the stump.

The TC prosthesis can be donned in a sitting position because the internal socket is detachable from the prosthesis and the valve is attached to the bottom central portion of the internal socket.

The internal socket of the TC prosthesis is not affected in any way while pulling out the cloth from the stump because the strength and flexibility of polyethylene socket are adequate. This is very convenient, especially for bilateral amputees and geriatric amputees.

A lightweight adjustable AK prosthesis made of polypropylene was developed for geriatric amputees by Irons (1977). This prosthesis cannot be used for heavy duty and its production is

rather complex and requires considerable time. On the other hand, the TC prosthesis is simple to produce, requires little time and is very light.

The lightest TC prosthesis is 2.1 kg and is being worn with ease by a seventy-four year old man with a mid thigh amputation.

The transparent polycarbonate socket was introduced by Mooney (1972). Although the transparent polycarbonate socket is useful in checking socket fitting, it takes a long time to produce and is difficult to modify. The socket fitting of the polyethylene socket of the TC prosthesis can be observed through the semi-transparent material of the internal socket.

The TC prosthesis is lighter than the conventional prosthesis, because the thermoplastic sockets in themselves are lighter than the polyester socket and can be attached directly without a wooden block. Due to the reduced weight of the thigh part of the TC prosthesis and a favourable disposition of all the stump soft tissues in the socket because of the valve position at the bottom central portion, a functional pendulum motion of the shank is achieved and favourable gait patterns have been observed in many TC wearers from the first day of training.

The overcoming of the stump perspiration problems should be a boon to people living in warm environments.

The concept of socket fitting which requires exactness of the socket shape and dimensions to the stump should change by the development and use of the flexible socket.

The strength and durability of the TC prosthesis have been demonstrated by the fact that some of the younger amputees using it are able to play baseball and to ski.

Conclusion

Since November 1978, 295 AK amputees, including 9 bilateral AK amputees, have been fitted with TC-1 prostheses. The various advantages of the TC prostheses have been demonstrated as described above. The durability of the TC-1 prosthesis has been proved by the fact that none of the 295 TC-1's have been broken in use. Since March 1980, the TC-2 prosthesis has been applied to 145 amputees, including 6 bilateral amputees, and satisfactory results have been obtained.

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