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DEVELOPMENT OF A THERMOPLASTIC BELOW-KNEE PROSTHESIS WITH QUICK-DISCONNECT FEATURE

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In recent years, considerable interest has been focused on the development of endoskeletal, modular systems for the various levels of amputation. Logically, such systems should be fully competitive with conventional fabrication techniques in regard to cost, ease and speed of fabrication, function, and weight. In addition, they should offer improved cosmesis and interchangeability of components. The most successful application has been in the hip-disarticulation case, and perhaps the least satisfactory has been in the below-knee case, particularly in reference to weight and expense. In an attempt to redress this situation, Richard Lehneis in conjunction with various co-workers has developed a below-knee prosthesis utilizing a pylon of commerically available polyvinylchloride pipe, a thermoplastic. (*See preceding article. Ed.*)

In their technique, one end of a piece of approximately 1¼ in. I.D. pipe is attached to a socket, cut to length, and a foot is applied by using an ankle plug of metal or PVC. Any alignment changes indicated by walking trials are made by heating and bending the pipe. The prosthesis can then be equipped with a cosmetic cover. This pylon has been used for immediate postoperative prostheses even though no quick-disconnect feature is provided.

Inspired by this, and at the instigation of Virgil Faulkner, C.P.O., the author late in the winter of 1973 began investigating the possibilities of developing a similar system from locally available materials. It soon became apparent that the smallest size pipe suitable and available locally is of about 1⅝ in. I.D. with a 3/16 in. wall thickness. PVC pipe of this size is used extensively in the plumbing trade, and therefore a wide variety of fittings is available for use with this size. Consequently, the decision was made to provide a quick-disconnect feature by utilizing some of these fittings. One method used consists of cementing a threaded male connector to the pipe and adding socket-attachment straps to the matching female connector. (Figs. 1 and 2).

For their original purpose, the mating pieces were designed to be softened by heat and/or a solvent cement before being screwed together. For our purposes, it has been necessary to reform the threads using heat and a tap and die impro-

Fig. 1. Various components of the plastic pylon. The primer and solvent cement are shown also.

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Fig. 2. An assembled pylon with galvanized straps.

vised from corresponding metal fittings (Fig. 3). Socket-attachment straps of conventional (and expensive) stainless steel have been used as well as less expensive straps of galvanized material that is generally used to hang water pipes (Fig. 1). These straps are attached to the female receptacle with machine screws, but pop rivets may be satisfactory. The resulting assembly can be laminated into a plaster-of-Paris rigid dressing, a Lite-Cast II temporary socket, or a polyester laminated socket (Figs. 4, 5, and 6). The last mentioned procedure results in a temporary prosthesis of particularly pleasing appearance (Fig. 7).

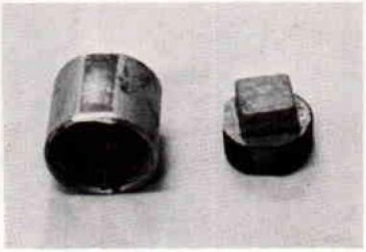

Fig. 3. Improvised tap and die showing flats and grooves needed for cutting threads.

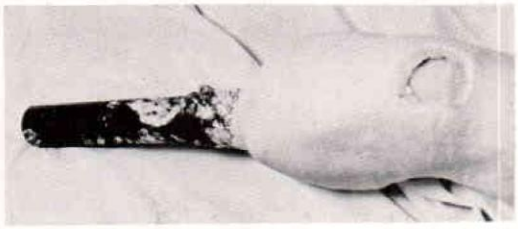

Fig. 4. Pylon laminated into a rigid dressing.

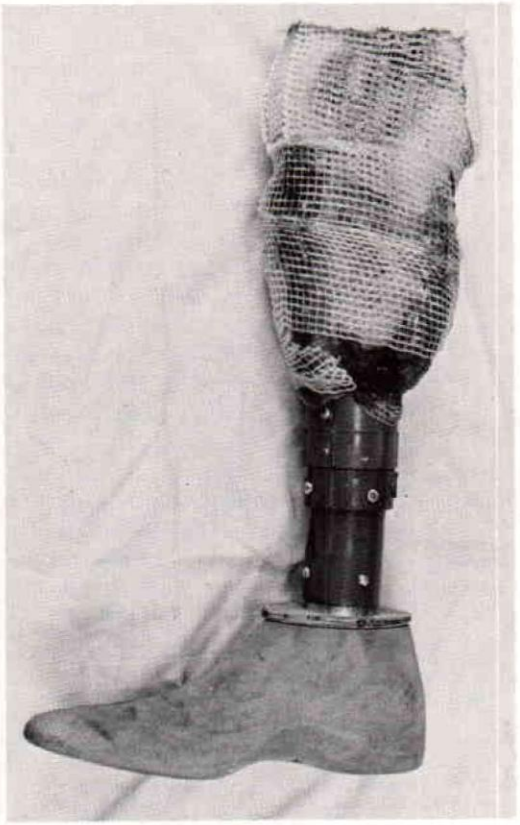

Fig. 5. Pylon laminated into a Lite-Cast II socket with foot attached.

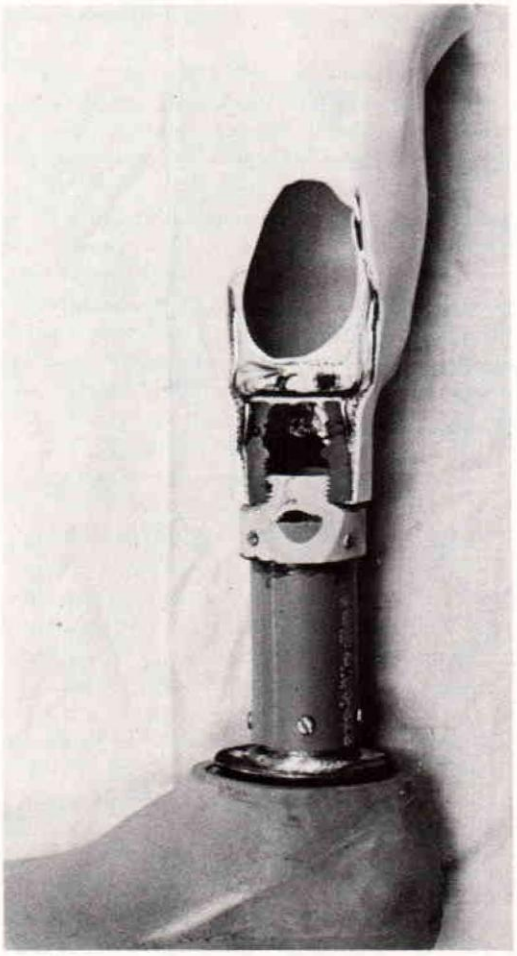

Fig. 6. Cutaway view of pylon laminated into a polyester socket.

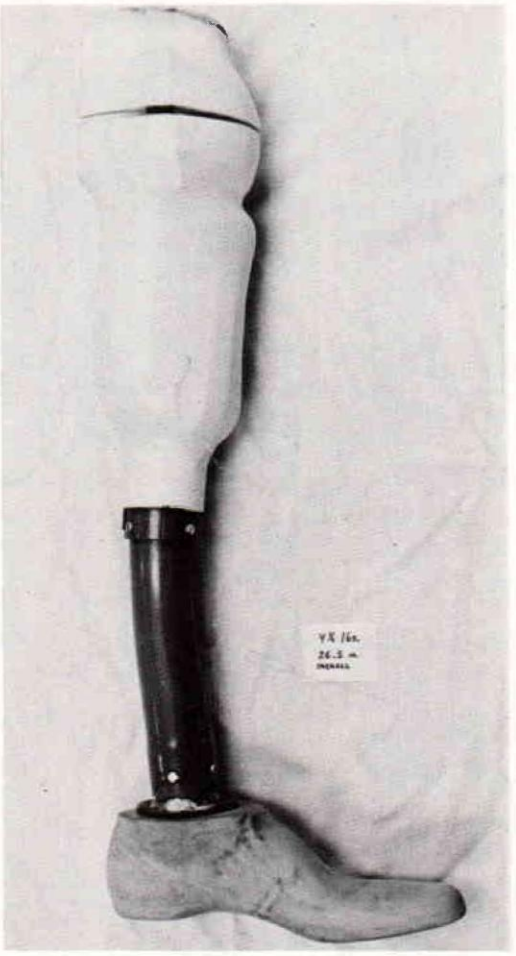

Fig. 7. Assembled temporary prosthesis.

Various ankle plugs have been used including some of modified PVC fittings, wood with adaptor nuts, and cut-down aluminum pylon tubes (Fig. 8). The latter have proven to be the most practical to date. Currently, work is under way to develop ankle plugs of either aluminum or PVC stock.

When using the pylon for an immediate postoperative prosthesis, a locking pin is provided to assure proper alignment of the various segments when the lower assembly is removed and replaced by the nurses and therapists (Figs. 1, 4, and 9). In surgery, the socket-attachment straps are incorporated in the cast and aligned while the pipe is still attached. The patient is "squared-up" and the pipe is marked at a point corresponding to the sole of the opposite foot; the pipe is then removed. The foot is then attached to the pipe making suitable allowance for the height of the foot.

When the female receptacle is laminated into a polyester socket, considerable care must be taken in aligning it to avoid the necessity of making excessive bends. While not detracting materially from the strength of the prosthesis, these bends can present quite a peculiar appearance. In this instance, no pin is used and the two sections are forcefully "screwed home" so as to insure that no slippage occurs during use. For maximum strength, the threaded end of each fitting should

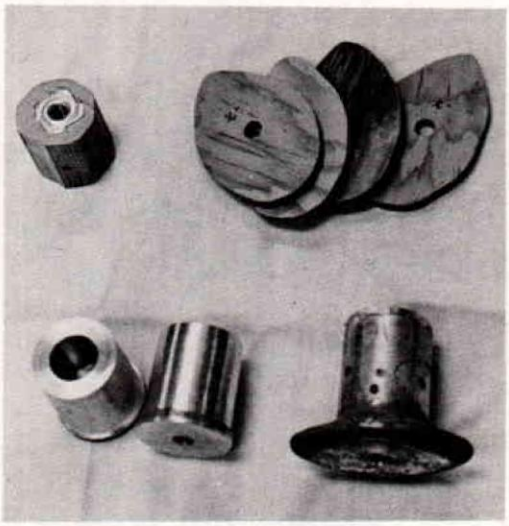

Fig. 8. Various ankle plugs and ¼ in. spacers.

Fig. 9. Disassembled immediate postoperative prosthesis with locking pin.

be resting solidly on the shoulder of the opposite piece. This has proven satisfactory to date, although additional security can be obtained by heating the male connector slightly beforehand. If desired, the two sections could also be cemented together, of course.

To make height changes readily possible, the prosthesis is assembled ½ in. short and the difference is made up with ¼ in. spacers, a number of which are on hand at the time of fitting (Figs. 5 and 8). Any bends in the pipe should be made in the proximal portion so as to leave the distal portion unaffected for better observation of results. While such changes are made readily, considerable heat is needed. The necessity for extensive alignment changes can be avoided with experience and if due care is taken in the laminating procedure.

This system has not yet been used in a definitive prosthesis as it is still in the process of being proven and refined. However, no significant difficulties can be seen as the work of others bears out. This system has been in general use for sometime now, and no significant failures have occurred. Some 15 temporary and 5 immediate postoperative prostheses have been fitted over a period of 6 to 9 months using these components. In the author's opinion, this constitutes a sufficient sampling over a sufficiently long period to warrant serious consideration of further development.

CONCLUSIONS

The foregoing portion of this article describes our early experience in the use of PVC pylons. Since January of 1974, our experience with this early system and our dissatisfaction with it have resulted in adoption of the system we are presently using. This system consists of a female connection made from a commerically available PVC slip-fitting coupling with three short galvanized straps fastened to the proximal portion with pop rivets. The connection to the pipe distally is made by either a simple pin or two machine screws and nuts. This modification eliminates the tedious recutting of threads that was necessary in the previous design as well as breakage. At the distal portion of the pipe, a PVC ankle plug fastened to the pipe by sheet metal screws is used to connect the foot. Due to the furor over the possibility of PVC causing cancer, the use of PVC solvent glue has been avoided lately.

These changes have simplified production and reduced the time required as well as eliminating the breakage that occurred formerly at the base of the threads of the male connector. Alignment changes of temporary prostheses have not proven to be a problem as attention to detail during socket lamination results in an alignment that commonly needs only minor changes. Because of the large external diameter of loosely available components (which results in increased bulk and weight), the system is not commonly used for definitive proestheses. Early attempts at fabricating soft cosmetic covers for a water-based foam recently available on an experimental basis from Alimed have been inconclusive. Here,

too, the external diameter of the pylon poses a problem.

The author wishes to make full acknowledgment of the work of Messrs. Lehneis and Wunder, as well as others in the New York area, and to point out that his own contribution has been in the matter of a quick-disconnect feature which seems to offer significant advantages. Furthermore, the development of a comparable commercial system at reasonable cost involving the use of such a disconnect feature and a smaller size pipe appears to be feasible. Such a commercial system should logically include an ankle plug of PVC and a locking pin on a lanyard for optional use.