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APPLICATIONS OF TRANSPARENT SOCKETS

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Among recent trends in prosthetics, perhaps the most significant is the transfer of the prosthetist's work from the "bench" to the clinical setting where he has a far greater interaction with patients. In many clinics this move has been facilitated by the application of modular prostheses (*6*), by introduction of improved plaster techniques (*1*, 2), and by use of transparent check sockets made with vacuum techniques (*4*, *5*). Through improvement of fitting techniques, use of check sockets provide substantial benefits to both the patient and prosthetist (*3*).

The transparent sockets are molded from strong, clear plastic in a heated, soft state. Almost any type of socket can be formed (Fig. 1). The use of transparent plastic provides a relatively inexpensive and expeditious means of direct visual assessment of the total-contact fit of the socket with respect to the stump. Because direct observation of the stump-socket interface

Fig. 1. Polycarbonate transparent sockets. Illustrated from left to right are PTB, PTS, Below-Elbow, Short Above-Elbow, Above-Knee and Symes.

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under static and dynamic conditions is possible, some of the obstacles to optimum fit and training such as stump pain and skin breakdown are substantially reduced.

Caution must be exercised when the patient is allowed to walk in vacuum-formed sockets because repeated application of loads can lead to work hardening and stress failure of the plastic. In short-term applications, this is no problem, particularly when the load-transmitting areas of the socket are reinforced.

MATERIALS AND METHODS

Using pre-heated sheets of Lexan, a polycarbonate developed by General Electric Company, transparent sockets are molded by atmospheric pressure over a positive plaster model of the patient's stump as described by Mooney and Snelson (*4*). Lexan is a strong thermoplastic material with a tensile strength of 6,000 N/cm^2 (8500 psi). Its very high impact strength, light weight, and transparency make polycarbonate highly desirable for fabrication of prosthetic check sockets.

Unfortunately, polycarbonate is hydroscopic. Any water absorbed from air results in bubble formation when the material is molded at elevated vacuum-forming temperatures, thus leading to significant loss of transparency and decreased tensile strength after molding is completed. This tendency toward bubble formation is augmented further by expanding volatiles trapped in the sheet of polycarbonate. Drying and dehydration by heating the sheet material at 135 deg. C. (275 deg. F.) for 36 hours prior to molding will substantially eliminate this undesirable characteristic. Although lower temperatures are also effective, much longer times are required for drying.

Depending on the size, strength, and durability requirements of the socket, a blank sheet of polycarbonate of either 10 mm. (3/8-in.) or 13 mm. (1/2-in.) thickness is selected. It is then cut to a size of 23 x 23 cm's. or 30 x 30 cm's. (9 x 9-in. or 12 x 12-in.) depending upon the size of the socket to be formed. Commonly, molding is initiated at 235 deg. C. (450 deg. F.) at 500-700 mm. (19–27-in.) of mercury vacuum.

Vacuum molding requires no elaborate equipment. Indeed, all needed machinery is readily available in most prosthetics facilities. A low-temperature oven for drying the plastic, a high-temperature oven for softening the plastic, a work stand, a vacuum pump, a ballast tank, valves, and tubing are the only items required. Figure 2 shows schematically the arrangement of the work stand and pumping system with a cross-sectional view of a plaster positive stump model in place.

Soft polycarbonate is pulled by hand over the positive model and contact-sealed against the circumference of the support surface before application of the vacuum through the central port. Firm contact and a tight seal will assure accurate reproduction of the positive model. The support surface on which the positive model rests is disconnected easily and, thus, is interchangeable. Three sizes of 18, 20 and 24 cm. (7, 8 & 9.5-in.) diameter plywood surfaces with soft rounded edges are used to support the various plaster models of the more commonly seen socket sizes. The diameter of the table should be no more than 5 cm. (2-in.) greater than the largest proximal diameter of the positive model. Proper selection of the table with respect to the diameter of the model will minimize "webbing" of the softened plastic and will result in a socket with a more uniform wall thickness.

The work table, pump, and vacuum tank may be arranged on a compact frame and should be located near the ovens in an easily accessible position. A simple arrangement is illustrated in Fig. 3.

At the start of the fabrication process, the positive plaster model is covered with a thin nylon stockinet to aid in air evacuation and positive mold breakout after socket formation. A blank sheet of polycarbonate that has been dried adequately is placed in a square metal

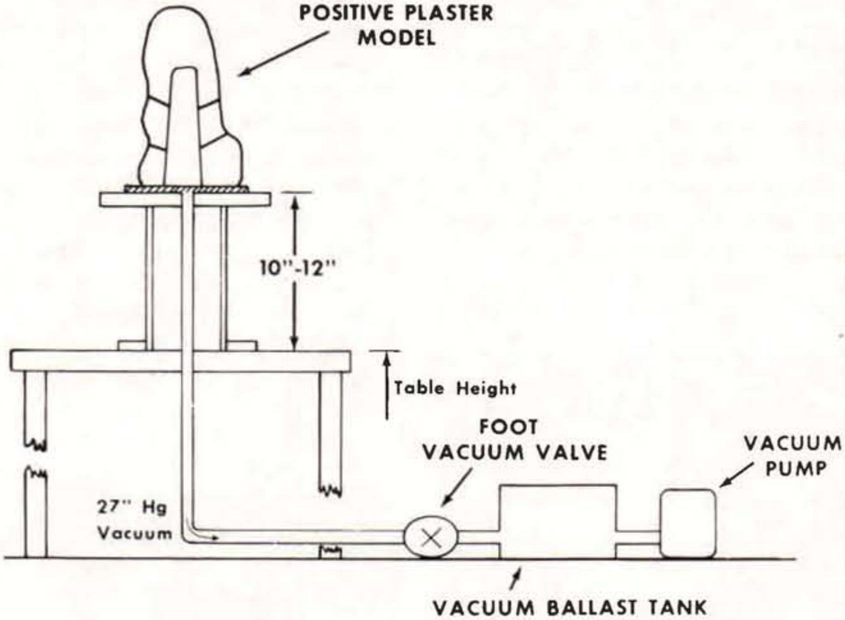

Fig. 2. Schematic drawing of the vacuum forming apparatus. Polycarbonate on the positive stump model is not shown.

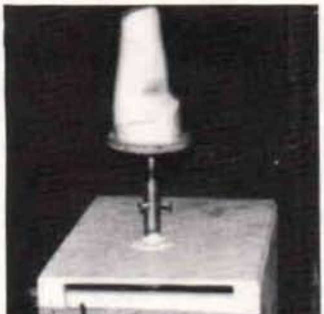

Fig. 3. Work stand with stump model on 20 cm. (8-in.) diameter support surface. Two controls are provided, the vacuum foot valve close to the floor and the electrical on-off switch for the pump near the top. Parts of the pump and ballast tank are visible at the center.

frame which is placed horizontally in a high-temperature oven. When the material begins to melt and sags to a point between 1/2 and 2/3 of the length of the plaster model, it is removed from the oven, turned over, and rapidly pulled down over the full length of the model. When contact and seal are established between the plastic and the edge of the support table, the pump is turned on with a foot-actuated valve and air is evacuated between the plaster model and soft polycarbonate. The higher atmospheric pressure exterior to the plastic surface forces the polycarbonate against the model, reproducing all of its surface detail.

During subsequent cooling, the transparent plastic hardens. The plaster model is broken out, and thus lost in the process. When further modification is required, a second plaster model may be formed from the first transparent socket. Following setting of the plaster, the first polycarbonate socket is cut away so that it can be removed without damaging the new model which is modified appropriately for formation of a subsequent transparent socket.

CLINICAL APPLICATIONS

BELOW-KNEE PROSTHETICS

In the past, transparent sockets have been used principally as check sockets to eliminate guess work in the fitting of prostheses. More recently, they have been used to help control edema. In an attempt to see if stump wrapping can be avoided several patients have been fitted with temporary prostheses, as shown in Fig. 4, with a removable transparent socket. The socket can be applied to the stump at night and held in proper apposition to the limb by a waist suspension system. The outer portion of the temporary prosthesis is a laminated polyester shell that provides reinforcement of the transparent socket and distributes on socket the load that is transmitted through the polyvinylchloride pylon. To facilitate insertion and removal of the socket, a slit is cut in the polyester shell with a slip-out rubber wedge laminated under it. Figure 5 shows the socket being inserted into the shell while the rubber wedge is held in place.

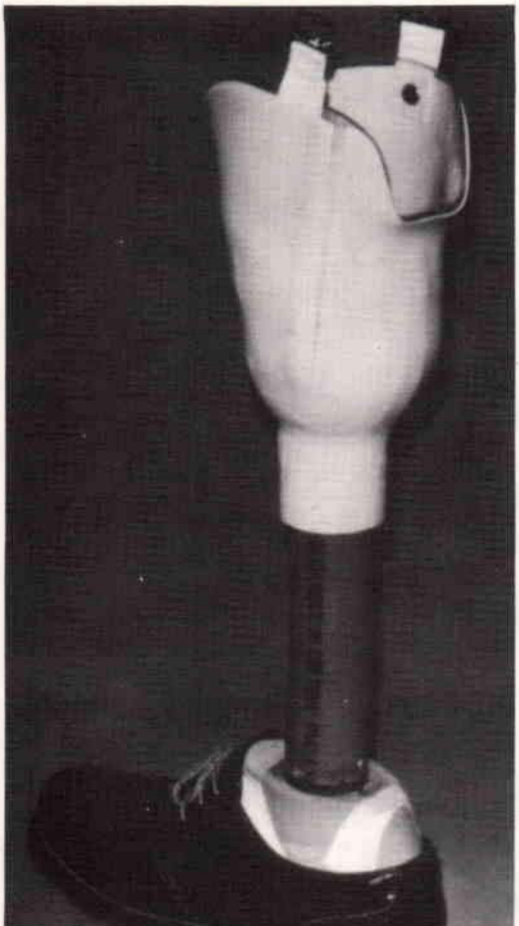

Fig. 4. Temporary BK prostheses with removable socket for edema control at night. The polycarbonate socket is enclosed in a polyester laminated outer shell for reinforcement. Note the split outer shell to facilitate removal. Not shown are the Velcro or tape used to close the split wall after reinsertion of the removable socket.

Fig. 5. Insertion of the socket into the outer shell while the rubber wedge is held in place just under the lateral slit. Suspension of the socket during the night is achieved by buckling the medial and lateral billets to a pelvic belt.

BELOW-ELBOW PROSTHETICS

Transparent sockets have been used in the fitting of externally powered, myoelectrically controlled below-elbow prostheses. Their use has facilitated proper fit and suspension over the humeral condyles and the olecranon. Concomitantly, the visibility of the socket has helped in properly locating the control electrodes over points of maximum electrical activity of wrist flexor and extensor muscle groups (Fig. 6). Consequently, even in the presence of extensive scarring and other skin alterations, critical electrode positioning can be accomplished successfully.

Fig. 6. Transparent below-elbow socket for myoelectric prosthesis. The points of maximum electrical activity marked on the skin are transferred to the outside of the socket after the muscle groups have conformed to and been distributed in the socket.

CONCLUSION

This clinical work, supported by the University of Virginia Orthopaedic Research Fund, has demonstrated the versatility and usefulness of vacuum-formed transparent sockets. The transparent sockets may provide visual assessment of static and dynamic socket fit, inspection of proper weight-bearing distribution across the stump surface, and more accurate determination of relief for bony prominences. Furthermore, transparent sockets are helpful in the accurate location of joint rotation centers and electrodes in the socket wall.

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