USE OF TEMPORARY PLASTER OR PLASTIC PYLONS PREPARATORY TO FITTING A PERMANENT ABOVE-KNEE OR BELOW-KNEE PROSTHESIS [a]

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HISTORY

Temporary or preparatory prostheses for use by lower-extremity amputees have been mentioned frequently and used occasionally for many years (1, 2, 3, 4, 5), but they have not been adopted readily in the United States. Many reasons have been given why preliminary fitting has not been done and these have included: 1. stump damage because of malfitting plaster or other temporary socket, 2. rapid shrinkage resulting in discomfort and stump damage because of change in contour of the stump, 3. development of persistent undesirable gait habits because of the absence of a knee joint, 4. a satisfactory preparatory prosthesis is almost as expensive as a finished limb, 5. it is cosmetically an inadequate device, 6. prosthetists do not have the time or desire to learn to use this mechanism, 7. if the principle of preparatory prostheses were good, it would be accepted readily and this has not been the case (6).

Preparatory lower-extremity prostheses have been used in the Orthopaedic Amputee Clinic at Duke University Medical Center since 1955 (7) and the Durham Veterans Administration Hospital since 1957. Originally, these were plaster sockets with wooden crutch extensions and were used primarily to assist with stump shrinkage in the above-knee amputee and early ambulation of this same group for physical and psychological reasons. These primary uses were then supplemented by an additional activity directed toward assessing an increasing number of geriatric amputees with vascular disease whose potential for successful use of a prosthesis was doubtful and whose limited public and

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private funds made trial and error with a finished prosthesis either impossible or impractical (8, 9, 10). The observations made during those early years of plaster pylon usage were gradually transposed to develop techniques applicable to above- and below-knee amputees in all age groups.

THE PLASTER PYLON

The prosthesis used initially in this study was made of plaster and was contoured proximally but resembled a plug fit. This was made by the physician in the Amputee Clinic without the aid of the prosthetist and with minimal effort toward alignment. This socket was gradually replaced by a total-contact quadrilateral socket of plaster that was hand molded over the stump and elongated by a crutch and suspended by a waist belt and/or a shoulder strap. Initially, patients were fitted at 4 to 6 weeks after amputation, with the early program including exercise and elastic bandage shrinkage. Once the plaster socket was applied, the patient was given gait instruction using crutches and then a cane, and allowed to take the pylon home to wear it as much as possible for direct weight bearing and constant compression. The patient was supplied with stump socks and felt to be added as shrinkage occurred and positioning of the socket became evident. Clinic visits were made bimonthly and the plaster socket was changed frequently.

As an outgrowth of this experience with over one hundred plaster pylons on both above- and below-knee amputees, several benefits were demonstrated: 1. The preparatory pylon was a satisfactory apparatus for assessing the prosthetic potential of the above-knee geriatric amputee. It allowed observation of balance, exercise tolerance, motivation, and the effects of ambulation on the opposite extremity. 2. The pylon was a more effective stump shrinker than elastic bandages or other similar devices. 3. Walking in the pylon provided an adequate exercise mechanism for hip musculature and proved to be an active means of diminishing or preventing flexion-abduction contracture of the hip. 4. The general condition of patients was aided by exercise and activity, and excessive weight was less obvious. 5. The emotional reaction of the patient in the form of depression following the amputation was less obvious with the early ambulation program.

The plaster pylon had several undesirable features: 1. Construction of the pylon by the physician in the amputee clinic was time consuming and inefficient. 2. Alignment of the pylon was difficult, and an optimum gait was not possible without a knee joint. 3. Rapid shrinkage and malfitting resulted in discomfort when full unassisted weight bearing was attempted. (For this reason crutches or canes were usually necessary during the pylon period. In spite of these problems, the benefits obtained from the use of the quadrilateral plaster socket encouraged

continuation of its use in the above-knee amputee.) 4. Attempts to use crutch-end pylons on below-knee amputees usually failed.

MATERIAL

As the number of patients using plaster pylons increased and with evidence that the below-knee amputee could be fitted with a patellar-tendon-bearing socket made by the prosthetist, it became evident that the prosthetist was the one to prepare the original temporary socket. The use of the New York University, VA Prosthetics Center, and the University of California at Berkeley molding brims, careful molding of the above- and below-knee sockets, and the addition of reusable aluminum knee-shin units, SACH feet, and appropriate suspension, allowed a pylon that approached a permanent limb in function but still maintained the advantages of using less expensive and reusable material. The pylon also furnished a principle of trial and error that had not been available to the prosthetist previously. The adjustments in alignment, possible by the Staros-Gardner alignment system (on VAPC pylons) and the Northwestern University below-knee pylon, provided an adjustable leg on an ambulatory patient that was light and functionally useful.

Certain structural problems with the plaster and the difficulty in obtaining maximum comfort led to the use of plastic laminate for the preparatory socket, with a cost that was little more than the plaster socket when material and labor were used in the determination of total expense. It is our firm belief that the prosthetist makes the best preparatory pylon, although the use of a temporary plaster socket for initial shrinkage or for assessment of the patient's ability to use a prosthesis is still a good approach by the physician who may not have a prosthetist nearby.

Table 1 gives information about 277 patients who have been fitted with a pylon. It indicates the outcome of their initial experience and their current condition.

Table 2 lists the reasons for amputation in this same group of patients recorded in Table 1.

TABLE 1.—*Patients Fitted with Temporary Prostheses 1/4/64—12/31/66*

	Total	Permanent prosthesis	Still on temporary	Taken off	Abandoned	Died	Right	Left
BK	114	98	14	0	0	2	63	51
AK	128	102	13	5	4	4	59	69
Bilateral	28	23	5	0	0	0	—	—
Hip disarticulation	7	5	1	0	0	1	4	3
Total	277	228	33	5	4	7	—	—

TABLE 2.—*Reason for Amputation of Patients Fitted with Temporary Prostheses 1/1/64—12/31/66*

	BK	AK	Bilateral	Hip disarticulation
Trauma	35	31	7	2
ASVD	22	44	9	0
ASVD with diabetes	22	29	7	0
Congenital	5	4	1	0
Neoplasm	5	8	0	5
Osteomyelitis	2	3	0	0
Frostbite	0	0	1	0
Gas gangrene	23	9	3	0
Total	114	128	28	7

INDICATIONS FOR FITTING A PATIENT WITH A TEMPORARY PROSTHESIS—PAST AND CURRENT

For this study, all amputees have been considered as candidates for temporary prostheses. Originally, a time interval of 6 weeks was allowed between amputation and fitting, but experience proved that an earlier time for application of the pylon was desirable. At the present time, the temporary prosthesis is made immediately after the initial clinic visit, which is usually 10 to 14 days following the amputation, or at the time that primary skin healing has occurred. This pattern has varied, however, since several amputation stumps were fit in spite of incomplete healing following delayed closure methods, chronic skin ulcerations, and persistent drainage for other reasons. None of these extremities showed deterioration of the stump unless a chronic deep infection was present.

In the past, the criteria used for determining an amputee's ability to use the lower-extremity prosthesis were based on his potential to develop a good crutch gait without a prosthesis, even though energy expenditure was less without crutches.

The use of crutches without a prosthesis required a greater total energy output than when an above-knee prosthesis is used without crutches (11), the energy being expended principally in the upper extremities and the trunk. Angina may occur when a three-point-crutch gait is used and disappears when the patient walks with the prosthesis. However, claudication may not be a noticeable problem until a normal gait pattern is utilized. All of these factors do not appear suddenly in the patient who is potentially a prosthetic user. If the permanent limb is applied as the first unit, any one of these elements may make use of the limb inadvisable. Thus, the emotional effort, as well as the financial loss, is detrimental to the elderly individual.

ASSESSMENT OF THE CONVENTIONAL PREPROSTHETIC PROGRAM

The standard preprosthetic program practiced in our clinic before use of the pylon, and the one that is still used in many areas of this country, consists of ambulation of the patient on crutches or with a walker as soon as strength and balance are adequate for this. A wheelchair is frequently provided for movement about the hospital or home, and the patient spends many hours a day in the sitting position. Exercises are used to strengthen the hip musculature in the above-knee amputee and the quadriceps and hamstring in the below-knee amputee. Attention is paid to total body weight, and stump atrophy is hastened by appropriate wrapping with elastic bandages or other elastic shrinkers, all of which must be reapplied several times each day. This requires the assistance of other individuals, particularly in wrapping the above-knee stump. The age and physical condition of the patient, especially those with poor coordination or weakness from chronic illness, make use of the shrinkers somewhat difficult. The young child, of course, needs assistance also. When the patient's general condition has reached a point of stability and the condition of the stump seems to be stable, then a prosthesis is prescribed and fabricated by trial and error. Actually, the determination of maximum shrinkage of the stump is frequently in error, as even tape measurements and manual compression are not sufficient. Adequate volumetric methods of determining stump shrinkage still must be developed. Several weeks' delay frequently occurred in the fitting of any type of a prosthesis because of differences of opinion between physicians, prosthetists, and patients. Also, fluctuations in body weight made it difficult to prescribe a permanent prosthesis in a patient who has lost much weight during the original phases of his illness and who was still in the process of stabilizing his weight.

Prior to the existence of the "adjustable leg," the prosthesis was ordinarily fitted in an unfinished condition, and the patient was allowed to walk in it for a short period in the prosthetic shop. Minor modifications were made as necessary. Frequently, the measurements were taken by the prosthetist, the limb was fabricated, and the patient never had the opportunity of applying the prosthesis until the finished limb was delivered to the home. Once the adjustable leg was available and accepted by physicians and prosthetists, more satisfactory alignment was possible.

Fitting and training were accomplished in a conventional program over a 1 to 3 week period, while the patient either lived at home if the prosthetist was nearby, was boarded in the community where the amputee clinic exists, or was kept in the hospital or rehabilitation center during the fitting and training period. It was during this time that the

physical therapist emphasized the exercise program and taught the amputee an appropriate gait, balance, coordination, and posture control, as well as exercises suitable for his age, endurance, and stump length. During this time, the therapist, the prosthetist, and the physician observed the patient frequently to detect necessary modifications of alignment and changes in the socket. Adjustments were necessary until the fit of the socket was comfortable and the gait was acceptable. Frequently, situations occurred that were not readily solved and these were aggravated by the weight of the adjustable limb, the patient's inability to walk for long periods of time because of fatigue, and the absence of a long enough period of time between adjustments to allow the patient to determine whether a change was actually helpful. A compromise was occasionally necessary when specific problems were not readily solved. This sense of urgency and occasionally exasperation was a disadvantage to the members of the amputee clinic team, as well as to the patient, and a cooperative attitude was frequently punctuated by conflict.

After the patient finally received his permanent prosthesis, additional experience in walking was necessary, and at the same time major modifications in the socket size and alignment became necessary. Thus, improvement in gait was delayed, frequent trips to the prosthetist were made, and considerable time was needed to accomplish these major changes.

If the conventional method of fitting a prosthesis either above-knee or below-knee is followed, a majority of patients will require a new socket for the above-knee amputee or a new prosthesis for the below-knee amputee within 6 months. This entire pattern of socket and limb modification has been difficult to explain to the patient, the sponsoring agency, and the family (12). This necessary change was fortuitous, as it allowed major modifications to be done with more certainty after a 6-month period of trial and error.

Adoption of the pylon program eliminated some, but not all, of these problems. Not until the use of the temporary plastic prosthesis was instituted as standard procedure for any amputee in the Duke Clinic, old or new, was it possible to provide a permanent prosthesis requiring minimal changes with a very low percentage of patients needing early replacement after the prosthesis was delivered. Thus, the pattern has been reversed and the members of the amputee clinic team were able to perform with greater certainty and accuracy.

CURRENT STATUS OF THE TEMPORARY PROSTHESIS PROGRAM

The plaster pylon and plaster temporary prosthesis have been replaced by a temporary total-contact plastic socket for all lower-extremity amputees regardless of age, reason for amputation, or level of amputa-

tion. The patient is interviewed, examined, and provided with a total-contact socket during the first clinic encounter. This may require an overnight stay in a motel, a graduated care unit, or a boarding house. While the prosthesis is being fabricated, the patient is receiving initial instructions in exercises and stump wrapping, and information concerning duration of walking, diet, and total care. Three sessions of gait training with the physical therapist are usually required and accomplished within a 3-day period, or the patient may return at intervals, depending on proximity to the clinic. The patient takes the temporary prosthesis home, begins the previously outlined program, and is oriented to recognize evidence of pressure, inadequate fit, or length discrepancies. The patient is seen by the members of the clinic team at weekly intervals for examination of the prosthesis, the opposite extremity, and his general condition. During the first few visits, the prosthetist makes adjustments in alignment of the prosthesis and performs minor modifications of the socket, making careful note of difficulties that might have occurred with the initial plaster mold, the bony prominences, the level of the knee joint, the position of the foot, or the length of the prosthesis. The therapist continues with gait instruction at each clinic visit and the patient's awareness of proper gait pattern is emphasized by repetition.

The patient is encouraged to resume full activity as quickly as possible in keeping with his physical and emotional condition. Many patients have returned to their usual work wearing the preparatory prosthesis.

When the temporary prosthesis is applied, X-rays in the anteroposterior and lateral planes are made with the patient in a standing position. This outlines the soft tissue contour and its relationship to the hard socket wall and allows localized filling, grinding of an uneven area, or other adjustments directed toward providing a comfortable total-contact fit and preventing undue localized pressure.

The patient is instructed to wrap the stump with elastic bandages at night or when the prosthesis is not being worn. The need for stump wrapping has not been eliminated by utilization of the preparatory prosthesis, but the elastic wrapping now assumes a less important role than it does when it is used as a shrinkage mechanism.

As shrinkage of the stump is recognized by the patient and the members of the clinic team, stump socks are added gradually to maintain total contact and adequate fit. As the stump usually shrinks more in its distal portion than proximally, short stump socks or cap socks are added as needed. When three five-ply wool socks are necessary to provide a reasonable fit, a new plastic socket is constructed. The number of new sockets has varied from two to six, depending upon the individual situation, averaging two in the above-knee and three in the below-knee amputee.

A permanent prosthesis is recommended when additional stump socks have not been added for at least 6 weeks, the patient's weight has been stabilized, an optimum gait has developed, and balance and coordination are adequate. The patient should be wearing the preparatory prosthesis all day with few complaints and admissible comfort.

The prescription for the permanent prosthesis is prepared with certainty, as information concerning socket modifications, suspension problems, knee stability, and foot position is available.

The adjustable limb is still used for alignment of the final prosthesis but the patient usually requires only an hour or two for fine degrees of alignment before the prosthesis is completed. One or two additional periods of gait training are necessary and these occur during the period when the adjustable limb is in place and when the final socket is delivered.

THE BELOW-KNEE TEMPORARY PROSTHESIS

The original below-knee patellar-tendon-bearing sockets were made of plaster of paris applied directly to the stump over a five-ply stump sock. This procedure was changed and the socket is now made of plastic laminate shaped over a modified plaster mold. Plaster sockets were more difficult to fit to the stump of the below-knee amputee than the above-knee patient. A hard socket, patellar-tendon-bearing prosthesis without socket insert has been satisfactory for the geriatric amputee as well as the younger patients, as the stump sock is all that is needed to protect the bony prominences, provided that a satisfactory total-contact fit has been obtained.

It was planned initially to add knee joints and thigh lacers but these have been rarely necessary in the geriatric patients. Most commonly, they were added for adolescent boys who required additional stability during competitive athletics or in any patient with a very short stump.

The plastic socket is molded by any of the available casting methods such as hand molding, Northwestern Ring Suspension, or VAPC molding plates (13). Specific directions are given in order to modify the positive mold depending on which technique is followed. When the soft insert is eliminated, the patellar-tendon bar must be more prominent, and all reliefs must be feathered into the mold to produce a smooth transition between pressure bearing and pressure relief points. The socket is attached to a reusable below-knee adjustable aluminum pylon shin with a laminated SACH foot attached.

Before the temporary prosthesis is finished, a weight-bearing X-ray of the stump in the prosthesis is made to determine the accuracy of fit. The X-ray of the leg-socket unit should show even contact between the socket and the stump. If air space is noted between the distal end of the stump and the socket, a hole is drilled into the socket and the

space is filled with silicone foam. If circumferential pressures are not even, or if the placement of the patellar-tendon bar is not exact, a new socket is fabricated over a newly prepared positive mold.

As a result of the observations gained during numerous experiences with the preparatory below-knee socket, several principles were established and transferred to construction of the final permanent hard socket prosthesis. Many of the problems associated with fitting and constructing the patellar-tendon-bearing prosthesis in the conventional way have been diminished by eliminating the socket insert and making the hard socket directly over a positive plaster mold. In the hard socket, friction on the skin is less and any piston action occurs between the smooth internal surface of the socket and the stump sock. Some resilience can be provided when necessary by fabricating the socket over a wool sock. Also, the unlined permanent socket can be washed and cleaned, thus avoiding accumulation of sweat.

The major inconvenience of this type of socket is its limited adjustability. However, adjustability in the permanent prosthesis is not as important if the principle of the preparatory prosthesis is used, as most of the stump changes have already occurred. If the lack of resilience is a major complaint of an individual patient, then air-cushion sockets with the distal end made of elastic rather than hard plastic have been used experimentally with some success.

THE ABOVE-KNEE TEMPORARY PROSTHESIS

The above-knee preparatory socket was originally made of plaster of paris, but during the past 3 years a plastic laminate total-contact socket has been used exclusively. The prosthetist has emphasized that the improved fit, the time saved resulting from fewer adjustments and replacements, plus the durability of the socket all justify the slightly additional expense. Total-contact principles have been used with the upper portion of the mold made in a quadrilateral shape, using a conventional molding brim as devised by New York University, the Veterans Administration Prosthetics Center, or the University of California at Berkeley. The socket, when completed, is mounted on a knee-shin unit, and a SACH foot is attached. Suspension is provided by a Silesian bandage when the amputation stump is long or by a pelvic band when the thigh segment is short. A suction valve is usually not used because of the rapid change in stump volume. A one-ply stump sock is worn initially, and additional socks are added as shrinkage occurs. The socket is changed when three wool stump socks are necessary to fill the space between the socket stump as in the below-knee stump. Socket fit is determined by direct observation, patient's complaints and response to questions, and by anteroposterior and lateral X-rays of the stump in the prosthesis taken in the weight-bearing position.

The preparatory prosthesis is bench aligned before the initial application. Additional adjustments of alignment are possible as the amputee improves his coordination and gait. Alterations of the prosthesis can include changes in the length, increase or decrease of foot rotation, medial or lateral placement, and increase or decrease of knee friction. The Hosmer pylon is versatile enough to resemble an adjustable leg even though all of the adjustments provided by the latter may not be possible. A knee lock is available and can be used for several days or even longer if the patient is unstable at the time the prosthesis is delivered, or if age and other infirmities make it undesirable to allow the knee to be unlocked.

The durability of the preparatory plastic laminate prosthesis with Hosmer shin has been sufficiently good to allow patients to undertake full activity after several days of prosthetic wear and to allow them to return to light work within a few weeks. Failure of material was noted occasionally when the plaster sockets were used but since the plastic laminate has been adopted, mechanical failures have been rare. Loosening of the foot bolt with rotation of the SACH foot has been the most frequent complaint.

UNUSUAL AND SPECIAL PROBLEMS AIDED BY THE USE OF THE TEMPORARY PROSTHESIS

1. The Bilateral Amputee

The bilateral amputee has difficulty with voluntary transportation as he cannot use crutches and must depend either on a wheelchair or on knee walking if both extremities have been removed below the knee. With one prosthesis in place, the patient may ambulate using crutches and may become less dependent on the wheelchair. Once it is evident that the patient's balance is sufficient to allow use of two prostheses, then a proper height must be determined for his particular center of gravity in order to provide maximum balance. The bilateral amputee has no sound extremity to assist him in lifting himself for sitting and must have a maximum fit between stump and socket as he uses this unit more strenuously and with greater leverage than does the unilateral amputee. This implies that unnecessary apparatus must be eliminated, excellent contact between stump and socket must exist, and optimal height of the prostheses, as well as appropriate foot size, must be determined. All of these conditions can be tested and tried with reasonable accuracy by using a preparatory prosthesis. This mechanism is more satisfactory than the usual adjustable limb because of less bulk and less weight. The patient can take the preparatory prosthesis home after several days of instruction and is able to continue his program at home with frequent visits to the clinic and to the therapist for addi-

tional assistance. Gait pattern is established over a period of several weeks rather than by strenuous concentrated instruction and adjustments.

The prosthetic potential of a bilateral amputee can be assessed much earlier utilizing the preparatory prostheses than if a long period of shrinking, conditioning, and fitting takes place before the patient has had a trial at prosthetic use. Furthermore, a sponsoring agency would spend a minimal amount of money in securing the preparatory limbs and at the same time obtain information about the future potential of this particular individual in permanent prostheses. All members of the clinic team as well as the patient will arrive at a decision that is mutually satisfactory concerning the desirability of obtaining one or two prostheses for the bilateral amputee.

2. Constricted or "Choked" Stump Syndrome

Choked stump syndrome is the result of intermittent ischemia of the distal segment of the stump with resulting thickened ecchymotic skin, crusting and eczematoid changes in the epidermis, ulceration, and edema as well as diffuse induration. These are some of the common complications of a stump where the majority of weight bearing is proximal in the socket rather than distributed uniformly over the entire stump. A smooth, carefully prepared total-contact socket will help solve this problem but the socket must be changed frequently because of rapid alterations in size and shape of the end of the stump.

Attempts at fitting this type of stump with an open end socket or a new permanent prosthesis usually result in failure. The temporary limb provides a practical means of allowing total contact and does it in an economically acceptable way. Full activity can be carried out during the period that the preparatory limb is being used, and long periods of adjustment of a permanent socket by liners and other types of fillers, as well as soft inserts, are not necessary.

3. Amputation for Malignant Tumor

The conventional management of a patient who has had a lower extremity amputated because of malignancy has included a waiting period of about 1 year before a prosthesis has been provided. This has been particularly true when a third party agency has been responsible for purchase of the prosthesis, both in children and adults. Certain tumors have a less satisfactory prognosis than others and the patients who have had amputation because of the more serious lesions are less likely to secure a prosthesis until a reasonably safe period has elapsed. This policy has been detrimental to the young patient from a psychological standpoint as it has contributed to depression, delay in returning to school, and, at times, social withdrawal. The need to use

crutches has made these individuals more dependent on others for various kinds of assistance, a constant reminder of the loss they have suffered.

Use of the temporary prosthesis has provided the individual with an inexpensive replacement that can be applied within a few weeks after the amputation; it allows continuation of a waiting period if this is necessary for financial reasons, but it provides dynamic conditioning of the stump and full activity until such time as it can be determined whether the patient should be provided with a permanent prosthesis. A certain number of patients never receive a permanent prosthesis, but those who have, benefited to the extent that this change in management of the amputee who has had a malignant lesion has been justified.

4. Immediate Postoperative Temporary Prosthesis

A natural outgrowth of the use of plaster or plastic socket within a few weeks after amputation has been a continued diminution of the time between amputation and fitting to a point where the preparatory plastic socket was applied in some instances at 5 to 7 days after the amputation. After hearing about the work of Weiss and discussing the problem with Burgess (14) and Golbranson (15), an experimental technique was agreed upon with the project to be carried out simultaneously at several centers with amputee clinic facilities. The first immediate postoperative prosthesis applied at Duke Medical Center was done in October 1964. A few of the patients have had conventional amputation techniques, after which a light dressing followed by sterile wool sock was applied, over which was wrapped a plaster-of-paris cast molded in a way similar to the preparation of the negative mold for plaster socket. A knee-shin unit and SACH foot were applied either the day of surgery or the day after, and patient was started on crutch walking with minimal partial weight bearing to the amputated extremity within 24 to 48 hours after surgery. The operative techniques utilized in the majority of the 38 patients done on the Duke Orthopaedic Service have included myoplastic techniques, anchoring fascia or muscle to bone after detailed preparation of the tibia or femur by smoothing, trimming, and filing, and leaving the periosteal cuff intact. The muscle is anchored to bone through drill holes and using absorbable sutures. Firm closure is obtained and suction drainage is utilized for 24 hours.

The technique has been successful in children particularly (16), but it can also be used with benefit in the geriatric patient. Minimal stump edema, rapid mobilization, and psychological advantages associated with this method appear to be the major advantages. Other benefits include rapid development of coordinated gait pattern, prevention of contracture, and the generalized improvement associated

with early ambulation. Four of the 23 elderly patients have had complications associated with use of the procedure. These were probably due to poor selection rather than the technique itself and included delayed healing of the stump in three instances and extensive skin loss requiring reamputation in one patient.

This is not a technique or program to be undertaken by a surgeon who does an occasional amputation. This program requires a surgeon who is oriented to the myoplastic technique and who can apply the temporary socket if the prosthetist is not available, or the presence or availability of a prosthetist who is willing to cooperate in this program.

SUMMARY

A temporary plaster or plastic pylon is helpful in preparing the amputee for a permanent prosthesis, but certain disadvantages of the pylon led to the development and production of a temporary total-contact plastic socket with a knee joint, aluminum shin, and foot which has proven to be the most satisfactory preparatory limb. Use of this mechanism and the program that accompanies it is strongly urged and recommended by all prosthetists and physicians prescribing prostheses, provided that they have had adequate instruction in utilizing the total-contact above- and below-knee prosthesis. The preparatory prosthesis will allow greater accuracy and flexibility in fitting the final prosthesis and many advantages in the use of the preparatory limb have been noted:

1. It provides a way of assessing patient's ability to use a prosthesis by observing balance, exercise tolerance, cardiac reserve, strength and circulation of the remaining extremity, motivation, and emotional condition.
2. It hastens stump atrophy and provides a stable stump in a much shorter time than has been possible by conventional methods of shrinkage.
3. It allows a period of maturation of the scar, osteophytes, and fibrosis of amputated nerve ends. Phantom pain has been less of a problem in the group of patients who have been fitted with a preparatory prosthesis.
4. It allows an accurate prescription of the permanent prosthesis.
5. It aids the prosthetist in becoming more expert in fitting all kinds of stumps and particularly those that are difficult.
6. It assists in the prevention of knee and hip contractures and diminishes or eliminates mild preexisting contractures at both these joints.
7. It provides a satisfactory mechanism for ambulation immediately or within a few weeks after amputation, and eliminates the psy-

chological and physiological problems associated with prolonged delay between amputation and conventional time of fitting.

8. It provides a physiological means of general body exercise.

9. It serves as a temporary device to allow full activity at minimal cost while means of financing a permanent prosthesis are being obtained.

10. It provides a trial mechanism for assessment of the bilateral amputee.

11. It provides the patient who has had amputation because of malignant tumor a means of early ambulation at minimal cost.

12. It aids the patient in converting from a prosthesis that is proximal bearing to one that has a total-contact socket.

13. It serves as a transitional apparatus between the plaster socket used for immediate postoperative fit and the permanent plastic socket provided when the stump has reached maximum shrinkage and stability, without major time or economic loss.

Appendix I

THE TEMPORARY PROSTHESIS

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Use of a temporary limb following amputations has undergone several periods of popularity and disfavor in recent years. Major disadvantages claimed by opponents of the preliminary prosthesis have included:

1. Manufacture by the clinic team is time consuming and results in a crude device unappealing to the patient.
2. Limb suspension is insecure, and faulty gait patterns result.
3. Stump breakdown occurs frequently due to poorly fitting sockets, particularly in the below-knee amputee.
4. Cost of a good temporary limb may approach that of a permanent limb.

Since 1957, temporary limbs have been used in the amputee clinics of the Duke University Medical Center and the Durham Veterans Administration Hospital. Initially, these limbs consisted of pylons made with plaster socket extended with a crutch tip and suspended by means of a pelvic belt or shoulder strap. Experience with over one hundred such limbs convinced the clinic team that the disadvantages of temporary limbs seldom occurred and were outweighed by the advantages. Refinements in manufacture of the preliminary prosthesis eliminated most of the problems and further demonstrated its usefulness.

Since 1962, the preliminary prostheses have been made by the prosthetist, using a quadrilateral total-contact plastic socket in above-knee amputees, and a patellar-tendon-bearing total-contact plastic socket in below-knee amputees. A reusable knee-shin and SACH foot are used in both, and a Hosmer adjustable knee is used in above-knee stumps. One hundred eighty-four preliminary prostheses of this type have been utilized.

Prior to the use of the preliminary prosthesis, a conventional postoperative program was adhered to; following healing of the wound, the patient was encouraged early to ambulate with crutches. Exercises to strengthen remaining muscles and to prevent contracture were taught. Stump shrinker bandages were used routinely, but were found difficult

to maintain in the above-knee amputee. The first limb was constructed after shrinkage was thought to be complete. However, further shrinkage frequently occurred with weight bearing, requiring socket liners or a new socket. Weight gain associated with inactivity complicated stump shrinkage. The period from time of surgery to first fitting was often 3 to 4 months.

With the use of the preliminary prosthesis, the patient is mobilized much more quickly. Ten to fourteen days after surgery, he is fitted with a temporary limb and gait instruction is begun. The limb is worn throughout the day, and the stump is wrapped at night. He is seen at weekly intervals, and necessary adjustments are made. The permanent prosthesis is prescribed when the stump size is stable and gait is considered optimal. The prescription is written according to the experience of the team with the temporary limb.

The additional expense and effort are more than justified by the following advantages observed:

1. Evaluation of the prosthetic potential is facilitated regarding the opposite extremity, balance, exercise, tolerance, and motivation, particularly in the elderly.
2. The bilateral amputee can be evaluated more thoroughly and allowed to crutch walk during the evaluation period.
3. Early ambulation preserves muscle tone, prevents contracture, and provides a needed psychological support.
4. Stump shrinkage is accelerated by weight bearing with no harmful effects to the stump.
5. Weight gain is partially controlled by activity.
6. Evaluation by the prosthetist provides a more accurate prescription for the permanent prosthesis and aids the prosthetist in fitting.
7. Full activity at less cost is provided early as compared with the previous program, where limited funds frequently made a trial at ambulation impractical.
8. Gait training is facilitated, and faulty gait patterns have not resulted.
9. Patients with amputations for neoplasm are ambulated early rather than waiting to determine whether the cost of a permanent prosthesis is justified.
10. Special fitting problems such as the choked, short, bony, or tender stump are made easier by allowing fabrication of various remedial sockets.

THE CONSTRUCTION OF A BK PYLON WITH HARD PTB SOCKET

The negative cast of the stump may be taken by utilizing any of the casting methods now being practiced. Modifications of the positive mold should be in accordance with the directions developed for the

individual molding technique with the following exceptions: 1. The patellar-tendon bar must be more prominent. 2. All reliefs must be feathered into the mold to provide a smooth transition from pressure bearing to pressure relief areas. 3. The proximal posterior edges must be determined and a plaster buildup added in this area to obtain a large radius for the hamstrings when the knee is flexed, distributing the pressure more evenly over this area.

The positive mold is then painted with a separating agent or covered with PVA.

If a dual vacuum system is available, it is preferable to use the vacuum to pull the PVA into the undercut areas of the positive mold.

The layup of nylon stockinet and Dacron felt is the same as the procedure described in the University of California at Berkeley manual on below-knee prosthetics published in November 1959. If the vacuum technique is applied to this layup, a more even thickness of wall in the socket will be obtained. When the socket is almost cured but still warm, a socket puller is used to remove the positive mold. If the socket is fully cured and cooled it should not be pulled off. The inside surface of the socket will be cracked in the undercut areas. Also if attempts are made to break the plaster mold out, the inside surface of the socket is often scarred, and a smooth, glass-like finish on the entire inside surface of the socket is desired.

Proximal edges of the socket are determined, trimmed, and finished by use of a felt cone on a high-speed arbor.

The socket is set in a balsa wood block with alignment as described in the University of California at Berkeley patellar-tendon-bearing manual. Bench alignment of the socket, pylon, and foot is obtained by the technique described in the same manual.

The socket is fit to the patient's stump using a heavy cast sock, a three-ply cotton sock, or a five-ply wool stump sock. It is preferable to start with a heavy cast sock, and as the patient's stump shrinks, other type socks may be added. The distal portion of the stump will usually shrink much faster than the proximal portion and very short cap socks are often necessary. When 20-ply stump socks on any area of the stump are required the socket is changed in order to obtain the proper pressure.

The patient is then instructed to walk in parallel bars. The patient's physical condition and ability to walk will determine how quickly optimum alignment of fitting can be accomplished. When the patient appears to be bearing a fair amount of weight on the pylon, a standing weight-bearing anteroposterior and lateral X-ray is taken to determine the fit of the socket.

If X-rays show total contact, the pylon is then reinforced at the points of attachment of the socket to the balsa wood block and the metal

shank to the socket using plaster bandage or fiber glass and plastic.

The patient is then sent with the pylon to physical therapy for gait training. As the patient's ability to walk improves, necessary changes in the alignment of the pylon are made by the prosthetist.

PLASTIC TOTAL-CONTACT ABOVE-KNEE PYLON

The negative cast and measurements of the patient's stump are taken by utilizing any of the current casting methods. Modifications to the positive mold should be in accordance with the directions developed by the individual molding technique.

After proper fit is obtained, management for the above-knee pylon is identical to that for the below-knee pylon.

The metal hip joint and pelvic belt are added for stability as rapid shrinkage of the stump occurs. A Silesian bandage is often adequate for the longer stump. A new socket is indicated when shrinkage results in the necessity for 15 or more thicknesses of stump sock for proper fit.

Appendix 2

THE CONSTRUCTION OF A PREPARATORY PROSTHESIS FOR A BELOW-KNEE AMPUTEE WITH A PATELLAR-TENDON-BEARING SOCKET

Bert R. Titus, C.P.O.

In the process of fitting below-knee amputation patients with preparatory patellar-tendon-bearing sockets, it has been found that elimination of the socket liner which is an integral part of the usual patellar-tendon-bearing prosthesis (1) has had merit. The "hard socket" preparatory prosthesis is currently manufactured as follows:

A negative cast of the stump is taken utilizing any of the casting methods being practiced: via hand molding, Northwestern Ring Suspension, or VAPC molding tool. Modifications of the positive mold should be in accordance with the directions developed for the individual molding techniques with the following exceptions: 1. The patellar-tendon bar must be more prominent than when a socket insert is used. 2. All reliefs must be feathered smoothly into the mold to provide an even transition from pressure bearing to pressure relief areas. 3. Proximal posterior edges of the socket must be determined and a plaster buildup added to this area to obtain a large radius for the hamstrings when the knee is flexed to distribute the pressure more evenly over this area.

The mold is clamped to a bench in the usual fashion and either painted with a separating agent or covered with a polyvinyl alcohol sleeve. If a dual vacuum system is available, it is preferable to use the vacuum to pull the PVA sleeve into the undercut areas of the positive mold. The procedure of applying nylon stockinet and Dacron felt that is described in the University of California at Berkeley Biomechanics Laboratory manual on the patellar-tendon-bearing below-knee prosthesis is carried out without modification. If the vacuum technique is applied to this layup, however, a more even thickness of the wall of the socket will be obtained. When the plastic socket is almost cured, but still warm, a socket puller must be used to remove the positive mold. If the socket is fully cured and cooled, it should not be pulled off as the inside surface of the socket will be cracked in the undercut area. Also, if attempts are made to break the plaster mold out, the inside surface of the socket is often scarred and a smooth glass-like interior surface is a desirable feature.

The proximal edges of the socket are determined, trimmed, and sanded in the usual fashion and finished by use of a felt cone on a highspeed arbor.

The plaster socket is set in a balsa wood block with a ½-in. plywood base glued to the distal end of the block. This will hold the screws in the metal pylon attachment plate better than the balsa wood.

Alignment of the plaster socket on the wood block and bench alignment of the socket, metal pylon, and SACH foot are obtained by the technique described in the California manual. The socket is fit to the patient's stump using a heavy cast sock, a three-ply cotton sock, or a five-ply wool stump sock. It is preferable to start with a heavy cast sock and as the patient's stump shrinks, other types and quantities of sock material can be added. The distal portion of the stump will usually shrink much faster than the proximal portion and very short cap socks are often necessary to fill this area. When 15 to 20 ply of stump sock on any area of the stump are required, the socket is changed in order to obtain the proper pressures. The patient is instructed to walk in parallel bars depending on his physical condition and his ability to walk in turn determines how quickly optimum alignment of fitting can be accomplished. When the patient appears to be bearing a fair amount of weight on the pylon, standing and weight-bearing X-rays in the anteroposterior and lateral projections are obtained to determine the fit of the socket. It has not in our experience been necessary to apply a radiopaque material either to the stump sock or the skin to determine these relationships. If the X-rays show total contact, the pylon is then reinforced at the points of attachment of the socket to the balsa wood block using plaster bandage or fiber glass and plastic. Necessary changes in alignment of the socket and the pylon are made by the prosthetist as the patient's gait develops.

Careful consideration is given to all principles described in the patellar-tendon-bearing manual in the construction of the preparatory prosthesis. The forces and pressures of this plastic socket are in the same relationship to the stump as the forces and pressures in the permanent patellar-tendon-bearing prosthesis. Therefore, there is little or no change in the shape of the stump when the patient goes from preparatory prosthesis to permanent prosthesis, providing maximum fit and alignment have been maintained throughout.

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