Evaluation of Synthetic Balata for Fabricating Sockets for Below-Knee Amputation Stumps

A. BENNETT WILSON, JR.¹

At the present time, most sockets for artificial limbs are made of a plastic laminate (usually polyester resin and Dacron) which has been molded over a modified replica of the stump. A replica of the stump is required because human tissues cannot withstand the temperatures generated by the exothermic reaction of the plastic as it cures. The replica is modified, using general rules established by research groups, in order to achieve a relationship between the stump and socket that is physiologically satisfactory, yet permits weight-bearing and provides stability. In addition, reliefs must be provided to accommodate bony prominences and any tender spots. A simple plaster-of-paris wrap will usually be too loose for normal use. Therefore, fabrication of plastic-laminate sockets with presently available materials involves at least the following steps (Fig. 1): (a) development of a female mold of the stump by wrapping the stump with plaster-of-paris bandages, (b) casting a male model of the stump by filling the female mold with plaster of paris, (c) modification of the male model by trimming away plaster in selected areas and building it up in other areas when necessary, and (d) lay-up and cure of the plastic laminate. The average time required to make a hard socket below-knee plastic prosthesis is eight man-hours.

It has been the goal of a number of research workers to find a simpler and less time-consuming method for fabricating satisfactory sockets for all levels of amputation. After many experiments involving a number of casting methods and a variety of materials, the Veterans Administration Prosthetics Center ² by 1961 had developed a technique for molding a socket of synthetic balata directly over a below-knee stump. The first successful results were achieved by using an air-pressure sleeve over a tube of synthetic balata,³ which had been softened by immersion in hot water (160 deg F) and then pulled over the stump (Fig. 2).

Upon the recommendations of the CPRD Subcommittee on Design and Development, the Subcommittee on Evaluation undertook responsibility for the evaluation of the new technique.

The claims of the development laboratory were: (a) a substantial decrease in elapsed time between measurement of the stump and production of a wearable limb, thereby speeding the rehabilitation process, (b) a substantial reduction in man-hours involved, (c) a capability for easy adjustment of the prosthesis at any time, and (d) a decrease in the amount of skill and training required to produce an adequate socket.

¹ Executive Director, Committee on Prosthetics Research and Development, National Academy of Sciences—National Research Council.

² 252 Seventh Ave., New York, N.Y. 10001.

³ From Polysar X-414 resin produced by the Polymer Corporation Limited, Sarnia, Ontario, Canada.
Fig. 1. Steps in the fabrication of a plastic prosthesis for a below-knee amputation. A, taking the plaster cast of the stump; B, pouring plaster in the cast to obtain model of the stump; C, introducing plastic resin into fabric pulled over the model to form the plastic-laminate socket; D, the plastic-laminate socket mounted on an adjustable shank for walking trials; E, a wooden shank block inserted in place of the adjustable shank after proper alignment has been obtained; F, the prosthesis after the shank has been shaped. To reduce weight to a minimum, the shank is hollowed out and the exterior covered with a plastic laminate.
PROCEDURE
A protocol (given at the end of this article) was developed and five clinics were asked to participate in the evaluation. The prosthetists from the clinics were trained as a group at the Veterans Administration Prosthetics Center on November 6-8, 1968. Each clinic was requested to fit five new amputees and five amputees who had worn PTB prostheses before, and provided with sufficient material and equipment to carry out the fittings.

Fig. 2. The air-pressure method of forming synthetic balata sockets for PTB prostheses: application of the tube to the lubricated sleeve of the stump; application of pressure to the sock-covered pressure sleeve; and the socket and bonded tubing attached with screws to the pylon.

RESULTS
Follow-up in the spring of 1969 revealed that all the prosthetists were encountering difficulty in obtaining adequate fits in nearly all cases except those with long tapered stumps, most of the sockets being too loose proximally. To overcome this problem, the VAPC devised a method whereby the air bag was eliminated, and molding pressure was

4 Rancho Los Amigos Hospital, Duke University, the University of Miami, the Veterans Administration Hospital/Los Angeles, and the Veterans Administration Hospital/Buffalo.
brought about by wrapping the softened balata tube with one-inch-wide elastic webbing and controlling the shape of the socket with the hands and fingers as it cooled.

All of the participating prosthetists were instructed in the revised method, and other prosthetists were instructed in the new procedure at the same time. Shortly afterwards, plastic pressure-sen-

Fig. 3 The tape-wrap method of forming synthetic balata sockets: application of pressure with elastic, pressure-sensitive tape; molding by hand to define the medial tibial flare and tibial crest; and the heated socket bottom joined to the pylon by an elastic tape wrap. (Courtesy Veterans Administration Prosthetics Center, New York, N Y )
sitive tape was substituted for the elastic webbing (Fig. 3) (3).

The results with the revised procedure were considerably better. The average synthetic balata prosthesis, with pylon but without cosmetic treatment, weighed 3 1/2 lb, and could be made in 2 1/2 hr. All of the claims of the developer were substantiated with the exception of the relative amount of skill required, a factor that would be very difficult to measure at this stage of development. At any rate, it is safe to say that no more skill is required for the new technique than for older methods.

All prosthetists who used the technique, with one exception, felt that synthetic balata is quite useful for temporary prostheses. Some have adopted the method as standard procedures where procurement practices permit use of temporary prostheses of this type.

CONCLUSIONS

When this technique is used, a considerable saving in time can be effected, and the patient can be provided with a prosthesis within a few hours. Furthermore, the use of synthetic balata permits easier adjustment of the socket later, and the adjustable pylon permits adjustment in alignment at any time.

It is therefore recommended that use by federal and state agencies of the VAPC technique for fabricating below-knee temporary prostheses be encouraged, and that the technique be included in the curricula of all below-knee prosthetics courses.

REFERENCES

The purposes of the study are:
1. To determine the usefulness of Polysar as a material for sockets;
2. To determine the usefulness of the Gardner technique of socket fabrication using the pneumatic bag;
3. To gather information on the use of pylon prostheses, including cosmetic treatment, for use by designers and manufacturers.

Each prosthetist is requested to fit five new patients and five patients who have worn PTB prostheses before. Instructions given in the VAPC manual should be followed as closely as possible.

A data-collection sheet including the Medical History Form A- and Lower-Extremity Prosthetic Information Form B-1 must be completed for each patient and held on file until requested by the CPRD staff. (It is not necessary to complete items 3, 4, and 7 on the Medical History Form.)

INSTRUCTIONS: FORM A

1. Site of Amputation
   Indicate side and level of amputation(s) being fitted. Use appropriate standard abbreviations—R for right, L for left. (E.g., right below knee = RBK)
   FQ = Forequarter
   SD = Shoulder Disarticulation
   AE = Above Elbow
   ED = Elbow Disarticulation
   BK = Below Elbow
   WD = Wrist Disarticulation
   PH = Partial Hand
   FP = Finger or Part
   HD = Hip Disarticulation
   AK = Above Knee
   KB = Knee Bearing (all cases using outside joints)
   BK = Below Knee
   SY = Syme
   FF = Full Foot

2. Type of Case
   New = Stump never previously fitted.
   Old = Replacement prosthesis. (Fill out item 14 regarding cause of replacement.)

3. Source of Patient
   a. List official name of amputee clinic and physician's clinic chief for all clinic cases.
   b. List name of physician who refers a non-clinic case.
   c. Check "Case Not Referred" in all instances where prosthetist writes the limb prescription.

4. Source of Payment
   The more common sources of payment for a limb are:
   State Bureau of Vocational Rehab.
   Veterans Administration
   State Crippled Children's Comm.
   Workmen's Compensation Company
   Insurance Company
   Public Welfare Agency
   Amputee or Family

5. Medical Complications
   Consult clinic physician or doctor who referred case for proper item (s) to be checked.

6. Condition of Other Extremities
   Include loss of toes, fingers or partial foot or partial hand amputations, if present.

7. Prosthetic Training
   If answer is "No," specify. The remark, "Previous prosthetic wearer," will apply in most cases where training is not prescribed.

8. Amputation History
   Many diabetic and arteriosclerotic cases have had one or more previous amputations involving one or both of their lower extremities. This form provides space for three such amputations. Do not record a "partial foot" as a separate amputation on this form. Record as a separate amputation a reamputation at a higher level. A high percentage of reamputations occur within the six weeks of the original amputation and are due to a failure of the wound to heal properly. Record the cause of such reamputations as "Failure of amputation to heal." These stumps are never fitted, so the items "Date Prosthesis Provided" and "Prosthetic Result" would be left blank. Multiple amputations that occasionally occur in injury cases should be recorded as a single amputation, listing the two or more levels (left above elbow and right below elbow as LAE-REB). In old amputations, if exact dates are unknown, record an estimate.

9. Level and Side of Amputation
   Use standard abbreviations as listed above.

10. Cause of Amputation
    For a correct diagnosis, consult with the clinic chief or physician who refers the case. One of the following listed causes will apply in nearly all cases:
    Injury (specify type)
    Arteriosclerosis
    Diabetes
    Malignant Tumor
    Thrombosis
    Embolism
    Eburnee's Disease
    Infection

11. Date Prosthesis Provided
    Record the date of the initial check-out of the completed prosthesis. Leave this item and the following item "Prosthetic Result" blank in all new cases since the tear-off Form A will be forwarded to the National Academy of Sciences before this information is known. At periodic intervals, you will receive a list of the new cases you have sent and, at that time, by referring to your facility copy of Form A, you will be able to furnish this information.

12. Prosthetic Result
    Consider the age and physical condition of the amputee as well as the purpose for which the device was provided in recording this item. In an elderly person, limited ambulation about his home might be considered as "Satisfactory."

13. Protective Surgery
    An increasing number of vascular cases are today receiving protective surgery to prevent or delay amputation. Consult the clinic chief or referring physician for type of procedure used. These include: sympathectomy, thrombendarterectomy, arterial grafts, and venous grafts.

14. Old Cases
    Indicate reason for replacing present prosthesis.

15. Remarks
    This space can be used to note any item of importance not covered previously or to add additional information on any of the above data items.
# Medical History

**Name of Patient**: [Name of Patient]

**Date**: [Date]

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
<th>Date of Birth</th>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Site of Amputation</td>
<td>2 Type of Case: New</td>
<td>Old</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 **Source of Patient (prosthetic prescription)**

- [ ] Amputee Clinic
- [ ] Clinic Chief
- [ ] Name of Physician
- [ ] Case Not Referred

4 **Occupation**

5 **Medical Complications (check conditions that can affect type of prosthesis or use of prosthesis)**

- [ ] Heart Disease
- [ ] Arthritis
- [ ] Serious Visual Impairment
- [ ] Mental Disease
- [ ] Obesity
- [ ] Other (specify)

6 **Condition of Other Extremities**

- [ ] Normal
- [ ] Vascular Disease
- [ ] Paralysis
- [ ] Other (specify)

- Amputee Received Pre-Prosthetic Training: [Yes] [No] [Specify]

7 **Post Prosthetic Training Prescribed**: [Yes] [No] [Specify]

8 **Amputation History**

9 **Level and Side of Amputation**

- Date of First Amputation
- Cause of Amputation (if congenital, describe)
- Prosthetic Result: [Satisfactory]
- [Unsatisfactory (specify)]

10 **Cause of Amputation**

11 **Date Prosthesis Provided**

12 **Prosthetic Result**: [Satisfactory]

- [Unsatisfactory (specify)]

13 **Protective Surgery**

- Date
- Procedure
- Extremity

14 **Replacement of Prosthetic (Type and Age)**

- [ ] Worn Out
- [ ] Outgrown
- [ ] Weight Gain
- [ ] Weight Loss

15 **Remarks**: [Specify]
INSTRUCTIONS: FORMS B-1 AND B-2

1. Forms B-1 and B-2 provide certain information that has already been entered on Form A. These items are repeated for the convenience of the shop worker.

2. Draw in approximate length and shape of stump to show a Syme, knee disarticulation, or hip disarticulation amputation level. Indicate location of stump abnormalities with an “X” and identify each “X” with appropriate code letters (e.g., Bs for bone spur, etc.). Use space under “Remarks” for additional information on any item.

3. Rx for Prosthesis: Record physician’s prescription. For example, “One PTB below-knee prosthesis.”

4. Give model name and/or number as provided by supplier of item.

5. In measurement diagrams:
   - ○ = circumference
   - □ = distance between two points
   - △ = diameter
**LOWER-EXTREMITY PROSTHETIC INFORMATION**

Name of Patient: 

Site of Amputation: Right Left

Clinic: 

Physician: 

(Show Location of Stump Details, Identify with Code Letters)

**BELOW KNEE**

<table>
<thead>
<tr>
<th>Anterior</th>
<th>Posterior</th>
<th>Medial</th>
<th>Lateral</th>
</tr>
</thead>
</table>

A = abrasion  
B = boil or skin infection  
Bu = bursa  
B = bone spur  
D = discoloration  
E = edema  
I = irritation  
M = muscle bunching  
P = pressure point  
R = redundant tissue  
S = scar  
T = trigger point

Stump Length: ____ inches

**ABOVE KNEE**

<table>
<thead>
<tr>
<th>Anterior</th>
<th>Posterior</th>
<th>Medial</th>
<th>Lateral</th>
</tr>
</thead>
</table>

**BELOW-KNEE STUMP CHARACTERISTICS**

- StumpMusculature: Soft Average Hard  
- General  
- Hamstring Group  
- Gluteal Group  
- Rectus Femoris  
- Adductor Longus

- Subcutaneous Tissue: Heavy Light  
- Ischium: Toughened Pressure Sensitive  
- Muscle Padding Prominent  
- Position of Trochanter: Anterior Midline Posterior  
- Previous Ischial Bearing: Yes No  
- Stump Lateral Convex Concave  
- Contour: Out Flat In  
- Degree of Contracture: Hip Flexion  
- Stump Adduction Abduction

Remarks:

3 Rx for Prosthesis:

- Foot Comp. Model  
- Knee Comp. Model  
- Socket Materials  
- Type of Symes  
- Hip-Joint Model Type

4 Ankle Comp. Model  

- Type of Socket  
- Shank Materials  
- Hip Diartic. Type  
- Type of Suspension

(Consult instructions on back for all items marked with numbers)
SYNTHETIC BALATA FOR BELOW-KNEE AMPUTATION STUMPS

LOWER-EXTREMITY PROSTHETIC MEASUREMENTS

Name of Patient ___________________________ Phone ___________________________ Date ___________________________

Address ___________________________ City ___________________________ State ___________________________

Male [ ] Female [ ] Date of Birth ____________ Height ______ Weight ______

Type Prosthesis ___________________________ Right [ ] Left [ ]

Shoe Furnished: One [ ] Both [ ] None [ ]

Shoe Lace Opening: Top [ ] In. Bottom [ ] In.

Extra Light-Weight Limb: [ ]

Extra Strong Limb: [ ]

KB or BK Knee Joints: Size ______ Style ______

Ankle Joint: Size ______ Style ______

KB or BK Thigh Lacing: Eyelets [ ] Hooks [ ]

Other: ___________________________

Thigh Lacer Height: ___________________________

Shoulder Loop Size: ___________________________

Waist Belt Size: ___________________________

Finish of Limb: Plastic Laminate [ ]

Rawhide Knotted [ ]

Color: Caucasian [ ] Negroid [ ]

Light Brown [ ] Medium [ ] Dark Brown [ ]

Check Strap: Lace [ ] Leather Strap [ ]

Measured by: ___________________________

Shop Alterations

Lengthen Thigh: [ ] In. Shorten Thigh: [ ] In.

Lengthen Shin: [ ] In. Shorten Shin: [ ] In.

KB or BK Lace Opening: Top: [ ] In. Bottom: [ ] In.

Set BK Lace on Joints:

Higher: [ ] In. Lower: [ ] In.

Lateral BK Joint Head:

Set In: [ ] In. Set Out: [ ] In.

Medial BK Joint Head:

Set In: [ ] In. Set Out: [ ] In.

Fit Foot In Shoe: Tight [ ] Loose [ ] Medium [ ]

Make Heel Cushion: Soft [ ] Medium [ ] Firm [ ]

Special Changes: ___________________________

Fitted By: ___________________________

Finished BK Limb, Knee Center to Floor: [ ] In.

Finished AK Limb, Ischium to Floor: ______ In.

Weight of Finished Limb: ______ lbs. ______ oz.

Special Features: ___________________________

Date Completed: ___________________________

8-2