THE RESULTS OF SLIP MEASUREMENTS IN ABOVE-KNEE SUCTION SOCKETS

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I. INTRODUCTION

Slip is defined, in this study, as relative motion between the stump skin and the socket. An excessive amount of slip may lead to abrasive injury, inadequate control over socket position and, ultimately, possible loss of the prosthesis. Conversely, lack of slip may conceivably reflect excessive restraint obtained by too tight a fit; implicit are large stump socket pressures.

This study was conducted to measure the extent of slip at various locations within above-knee suction sockets. The range of total slip values encountered in four subjects is given as a function of location within the socket, under conditions of level walking.

II. INSTRUMENTATION AND TEST PROCEDURE

A. Sockets

The sockets employed in these tests are duplicates of those normally worn by the subjects. Accurate duplication was insured by first taking male impressions of the subjects' regular sockets. Detailed information concerning the socket and insert procedures has been given elsewhere (1).

Each socket contains a series of inserts (small tubes mounted perpendicular to the inner surface of the socket walls) permitting the installation of the slip gage at a desired test location. Typically every test plane (horizontal) has two sets of opposed inserts.

B. Slip Gage

In principle, the slip gage consists of a pen rigidly held to the socket, whose inking tip is in light contact with the skin. As the skin slips with respect to the pen, an ink mark is drawn on the skin. The length of the mark is a direct measure of the slip; the orientation of the mark is a measure of the slip direction.
In practice (see Fig. 1), the slip gage is housed in a Plexiglas plug containing an O-ring which permits sealing against the insert. Thus air leakage around the gage is prevented. The pen tip (Paper Mate Flair Refill, Black H-7) is made of porous nylon, making possible a soft contact with the skin. Despite the lightness of contact, quickly drying ink is transferred readily to the skin, even under conditions of heavy perspiration. The pen choice is critical.

**C. Test Procedure**

The subject first dons the experimental leg with all inserts plugged. After some preliminary walking to check for comfort and fit, the plugs are removed (one at a time) and the slip gage inserted. The subject then walks approximately 30 steps (goal and return) at a cadence of his own choice. The slip gage is then removed and a flashlight used to note the magnitude and direction of the ink mark placed on the subject’s skin. Judging the size of the imprint is a process of low accuracy.

**D. Data Handling**

The means of assessing the data are consistent with the non-precise reading of results. As the accuracy of the assessment of relative motion is limited to ± 1/32 in., the data are simply sorted into three categories as follows:

- 0 - 1/16 in. relative motion = small slip
- 1/16 - 1/8 in. relative motion = medium slip
- 1/8 - 1/4 in. relative motion = large slip

"appreciable" slip

Any machineable rigid plastic would have been equally satisfactory.
It should be noted that the small slip category includes zero slip, that the class boundaries are not equal in size, and that no reading larger than $\frac{1}{4}$ in. was found in this work. The class boundaries are, of course, arbitrary and reflect only considerations of convenience.

E. Test Subjects

Four male above-knee amputees have been tested for slip. Certain of their characteristics are given in Table 1. Subjects have been arranged in the order in which they were processed.

III. RESULTS

A. General

When all test subjects and test locations were lumped together so as to obtain a composite view of slip, the results (see Fig. 2) indicate the great bulk of all observations (79 percent) fall within the zero to small slip class. While medium slip (9 percent of all observations) and large slip (12 percent) values appear in sufficient quantity to signify slip can and
does occur, the results suggest that "appreciable" slip motions are to be viewed as atypical.

Separating "appreciable" slip (>1/16) motions from all observations and plotting frequency of occurrence as a function of vertical location within the socket, i.e., plotting as a function of height, where

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\frac{\text{No.} \times > 1/16 \text{ at given height}}{\text{total observations at given height}}
\]

for lumped subjects, results in Figure 3. The distal end of the stump is taken as the "zero" plane and all vertical locations normalized on a stump length basis, resulting in a survey of slip over the lower 84 percent of the stump. In this manner direct comparisons of varied stump length subjects are possible. The results show that the distal portion of the socket is subject to the highest frequency of "appreciable" slip. Close to the brim "appreciable" slip is infrequent, and on the anterior and lateral brim no "appreciable" slip has been detected at any time in the course of these tests.

With respect to "appreciable" slip locations relative to horizontal socket coordinates, no clear trend appears in the data. It may be said that slip
occurrence on a given horizontal plane shows no directional bias, such as anteroposterior as opposed to mediolateral.

The slip trace itself has the general form of a filled-in ellipse. At one limit, the ellipse takes the form of a filled-in circle, while at the other limit, the trace is but a thickened line. Both limit forms appear in the data. The orientation of the major trace axis generally has a large vertical component, but in no case is the slip entirely vertical. Thus for large slip, it is generally true that both horizontal and vertical components of slip are large, suggesting a simultaneous axial and torsional displacement.

In only two instances was the trace unfilled, suggesting precise duplication of slip in successive steps (any lack of repetition in a series of steps acts to fill in the trace). As the overwhelming majority of traces were filled-in, it follows that “appreciable” slip, once initiated, has a random quality within the confines of its trace envelope.

B. Fit and Slip

Thus far, those results presented have been on a lumped subject basis, in which the quality of fit was averaged over the test group. To obtain a sense of the effect of fit, the socket of a single subject, N, whose measured percentage of “appreciable” slip was the largest of the subject group, was
reworked. Thus subject N was chosen partly on the basis of large measured slip; a further basis was unsolicited complaints about the nature of the fit ("looseness"). It should be noted that all other subjects regarded their socket fit as proper.

A series of horsehide liners were inserted in the socket of subject N covering the entire inner surface except those zones in which the slip gage was to be mounted. The revamped socket was deemed a "better fit" by the subject. Slip tests indicate that the revised socket does reduce the number of "appreciable" slip points by a factor of two; the resulting frequency of total "appreciable" slip points closely approximated mean values for the entire subject group.

In two other cases (subjects J, K), where preliminary test results indicated a larger than average degree of "appreciable" slip, repeat runs after removing and replacing the socket showed much lower frequencies of "appreciable" slip.

IV. CONCLUSIONS AND DISCUSSION

In what follows the reader is reminded that we have examined only four above-knee subjects with respect to slip, a sample so small that statistically valid conclusions are not possible. Still, certain trends in the data are of interest. These are:

1. Slip motion is limited to small fractions of an inch. Never greater than $\frac{1}{4}$ in. even in the case of a poorly fitted or improperly donned socket, most slip motions are $\frac{1}{16}$ in. or less.

2. The frequency of occurrence of extensive slip is small in a well fitted, properly donned socket.

3. The nature of fit, including the precise manner of donning the socket, is the key factor in minimizing slip.

4. Extensive slip occurs most frequently in the lower half of the socket and decreases as the brim is approached; in no case does slip occur on the anterior and lateral brim.

Slip distribution is roughly similar, although inversely related, to that of perpendicular pressure within a socket (1). Thus, where "appreciable" slip frequency is high, stump-socket interface pressures are low and vice versa. This finding may be viewed as a slip rationale, i.e., slip results from insufficient skin friction, in turn due to a lack of local perpendicular pressure. Within this context low slip is a reflection of adequate perpendicular pressure, and the art of fitting is concerned with providing that minimum perpendicular pressure everywhere within the socket just sufficient to prevent or minimize slip while maintaining an adequate seal. Such a rationale, while primitive in its failure to consider the stump shear modulus role, may be helpful nonetheless as a first approximation.
V. SUMMARY

The extent and frequency of slip within above-knee suction sockets have been measured for four subjects. Slip is found to be a generally small and infrequent characteristic, whose occurrence is highly dependent on the precise nature of fit. When present, slip is most likely to appear in the lower half of the socket and to decrease in frequency as the brim is approached.

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REFERENCE