

# Radiographic Evaluation of Stump-Socket Fit<sup>1</sup>

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The critical relationship between accurate fit of a prosthesis and amputee comfort and function constitutes the foundation of all prosthetic fitting. Consequently, one of the most important features of a lower-extremity prosthesis is the distribution of the pressures applied to the stump by the socket. Since World War II, considerable progress has been made in the design of sockets, leading to the widespread use of "total-contact" sockets for amputations at all levels. However, reliable objective information regarding the relationship of the stump to the socket below its proximal brim is masked by the opaqueness of the socket material. The use of conventional materials (*e.g.*, chalk, talcum, clay, and lipstick) to determine the adequacy of fit and the achievement of total contact has proved of limited value in the accurate diagnosis of fitting problems.

The use of X-rays as a means of checking stump-socket fit has been discussed by several investigators (1-5). Conventional X-ray films of the stump in the socket from the front and side under weight-bearing conditions have been of considerable value in determining total contact, fit, and alignment, but the films obtained by conventional techniques do not always reveal a clear demarcation between the soft tissues of the stump and the inner surface of

the socket (5). A radiographic method or procedure that would consistently give an adequate visualization of the stump-socket interface would provide valuable information for the physician and for the prosthetist in fitting patients. Such a procedure would also contribute to overall knowledge in this area of prosthetics, and this knowledge would aid in teaching the proper fabrication of sockets.

Some preliminary experimental work relevant to the above-stated deficiency, reported by Dr. N. C. McCollough, involved the topical application of an X-ray contrast material to the skin of the stump (5). Two or three coats of a saturated solution of sodium iodide in absolute alcohol were applied to the stump with a sponge and allowed to dry. The usual number of stump socks were then applied, the stump was inserted into the prosthesis, and films were made under weight-bearing conditions in the anteroposterior and lateral projections. The films obtained by this method provided a clear outline of the periphery of the stump, and any lack of total contact was easily recognized.

The purposes of the present study were to assess the value of radiopaque materials in the evaluation of stump-socket fit on a broader basis, and to develop a satisfactory procedure for routine clinical use in determining achievement of total contact and in diagnosing pressure problems more accurately.

## SAMPLE

The sample for this study consisted of 16 adults (15 males and 1 female), of whom 8 were below-knee and 8 were above-knee amputees. The below-knee prostheses

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were the patellar-tendon-bearing type, with and without Kemblo inserts. The above-knee prostheses had quadrilateral sockets of various types: wood open end, wood distal air chamber, and plastic total-contact suction socket.

Prior to participation in the study, each prospective subject was questioned concerning previous X-ray exposure and allergy to iodine solutions, in order to exclude patients with a history of extensive X-ray exposure or iodine sensitivity. A statement of informed consent was executed by each subject.

#### METHODOLOGY

The study encompassed investigation of the following radiopaque materials and X-ray techniques.

#### MATERIALS

1. Hypaque-M, 90% (Winthrop): An aqueous solution of sodium and meglumine (methylglucamine) diatrizoates, water-soluble organic compounds, used primarily as a contrast medium in studies of the cardiovascular system. Each milliliter supplies 462 mg of iodine.

2. Sodium iodide: A saturated solution in absolute alcohol.

3. Sodium iodide: A saturated solution (44%) in isopropyl alcohol (70%). Each milliliter supplies 374 mg of iodine.

#### PROCEDURES

Two or three coats of the contrast medium were applied with a sponge to the entire surface of the stump; the skin was allowed to dry between coats. The procedure was varied by also applying the contrast medium to the inner surface of the socket insert, and by applying lead foil on pressure-sensitive tape to the inner surface of the socket (or socket insert) as a radiopaque marker. The patient then donned his prosthesis, and weight-bearing films were made in the anteroposterior and lateral projections, using either high-speed screens or Kodak Royal Blue Ready-Pack Medical X-ray Film.

The X-ray unit used was a Westinghouse with an 85-kv peak capacity, and the settings were varied from 100 ma, 1/2 sec, 70 kv, 36-in. tube distance, to 100 ma, 1-1/4 sec, 85 kv, 36-in. tube distance, depending on the type of film.

Additional films were taken *without* application of a contrast medium to the stump for half of the subjects. Also, in several instances films were taken while the artificial leg was bearing no weight, *i.e.*, in the mid-swing position.

#### RESULTS

The techniques used in this study were very satisfactory in providing a definite outline of the periphery of the stump. The films demonstrated a sharp demarcation between the soft tissues of the stump and the inner surface of the insert or socket, thereby clearly indicating the presence or absence of total contact and identifying pressure areas more accurately.

With the X-ray equipment used for this study, the optimum settings were determined to be:

High-Speed Screens: 100 ma, 75 kv, 1/2 sec, 36-in. distance

Ready-Pack Film: 100 ma, 85 kv, 1 sec, 36-in. distance

Excellent results were obtained with all three of the contrast media, and no significant differences were noted in the films obtained with the three solutions. The saturated solution of sodium iodide in absolute alcohol dries on the skin a little more rapidly than a saturated solution in isopropyl alcohol 70%, but because of Federal regulations, detailed record-keeping is required when absolute alcohol (ethanol) is used. Hypaque-M, 90%, while more expensive than a sodium iodide solution, has the advantage of being commercially available and therefore not requiring the services of a pharmacist for its preparation. Because the iodine compounds are highly water-soluble, they are readily washed off the skin with water after completion of the X-ray exposures. No adverse effects (*e.g.*, skin eruptions) were mani-

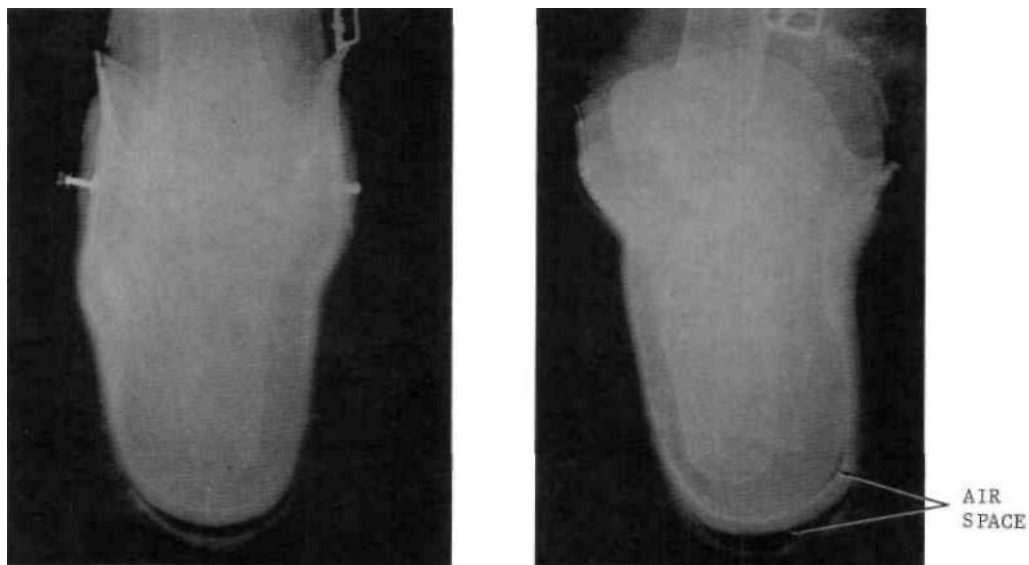


Fig. 1. *Left*, anteroposterior and *right*, lateral weight-bearing views of a below-knee stump, coated with contrast material, in a *well-fitting* PTB socket. Note excellent contact between stump and insert except for small air space posteriorly at distal end. Note also the undesirable space between insert and socket at distal end.



Fig. 2. *Left*, anteroposterior and *right*, lateral weight-bearing views of a below-knee stump, coated with contrast material, in a *poorly fitting* PTB socket. Note lack of distal contact and inadequate bearing on the patellar tendon.

fested by any of the patients as a result of these preparations.

Application of a contrast medium to the inside of the Kemblo insert (leather

backed by rubber) or the inside of the socket (plastic or wood) was not found to be necessary in order to secure satisfactory results. The rubber backing of the Kem-

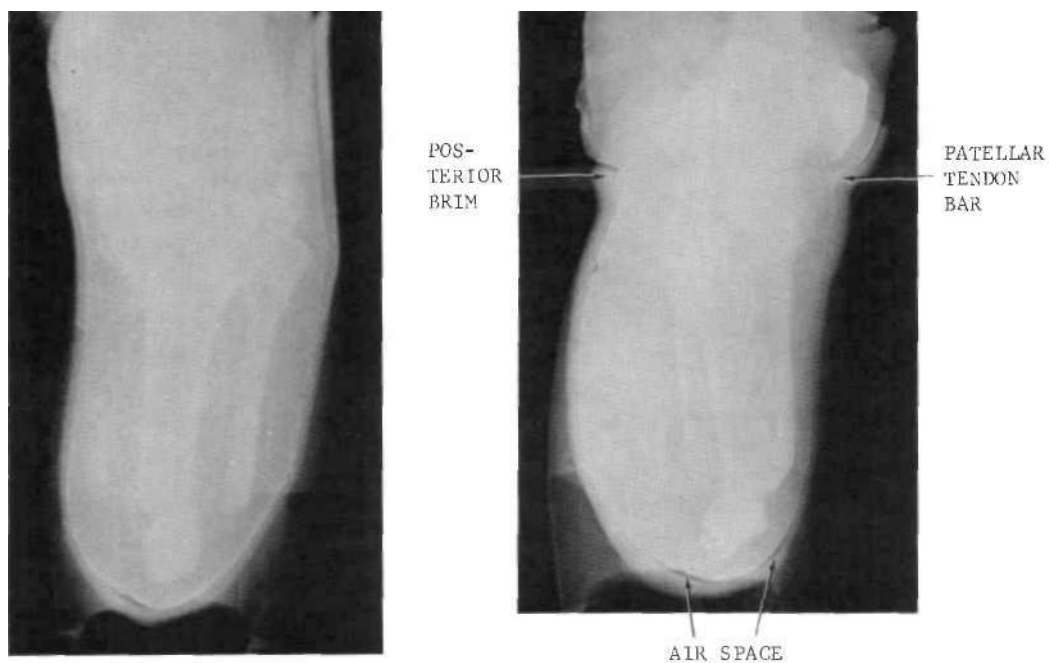


Fig. 3. *Left*, anteroposterior and *right*, lateral weight-bearing views of a below-knee stump, coated with contrast material, in a hard-socket PTS prosthesis with medial condylar wedge. Note that total contact is satisfactory, except for small air spaces at distal end, but the patellar-tendon bar is too high and the posterior brim is insufficiently flared to provide an adequate shelf in the popliteal area. Note also (*right*) the apparent increased radiodensity in the patellar-tendon weight-bearing area.

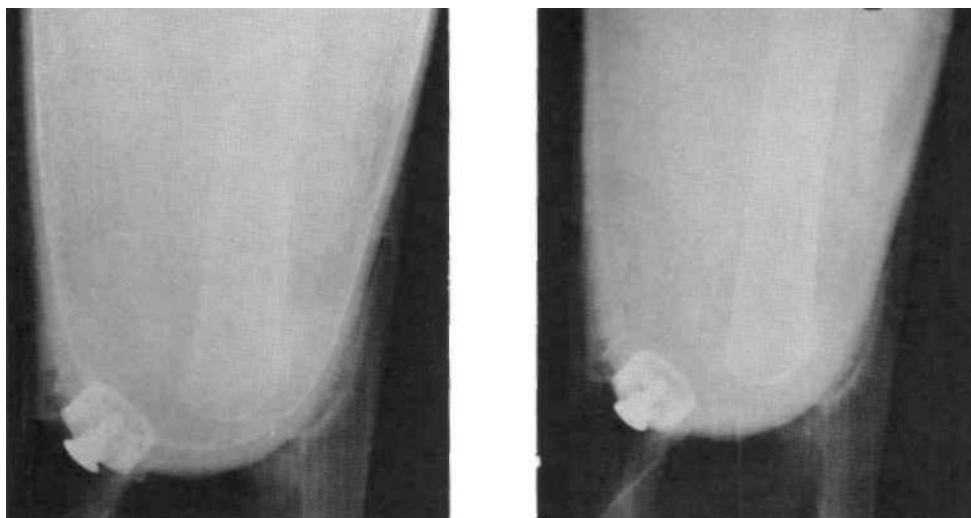


Fig. 4. *Left*, anteroposterior weight-bearing view of an above-knee stump, coated with contrast material, in a plastic hard-end total-contact suction socket. Note clear delineation of the stump-socket interface, showing excellent total contact. *Right*, conventional anteroposterior weight-bearing view of same stump and socket, using same X-ray settings. Note blurring of stump-socket interface.

bio insert and the plastic or wood of the socket are adequately radiopaque for clear demarcation of the inner surface of the prosthesis. The films obtained with the additional step were only marginally superior to those obtained without it, and furthermore, the contrast media tend to stain socket materials, particularly leather.

In several instances, lead foil was used successfully as a radiopaque marker of the interface between stump and insert, particularly in cases involving a removable distal-end pad which was not satisfactorily delineated otherwise. This material is available from the Minnesota Mining and Manufacturing Company as Pressure-Sensitive Tape #420-Lead Foil.

Examples of films obtained after application of a contrast medium to the stump are shown in Figures 1, 2, and 3. The periphery of the stump is clearly outlined in the films, so that the accuracy of socket fit may be readily determined: whether there is total contact; whether the suitable weight-bearing areas of the stump, such as the patellar tendon, the popliteal space, and the medial and lateral condyles, are being utilized to the best advantage; and whether adequate reliefs have been provided for the head of the fibula and the tibial tubercle.

Inspection of the contrast-medium films for objective indications of stump-socket pressure gradients tentatively suggests, as also remarked upon by McCollough, that areas of compression (*e.g.*, over the patellar tendon) show increased density of the contrast material. An example of this phenomenon is shown in the lateral view of Figure 3, where increased radiodensity is apparent in the patellar-tendon weight-bearing area.

Although X-ray films obtained by routine methods, without the use of a contrast medium, provide considerable useful information about stump-socket fit, they do not always reveal a clear demarcation between the soft tissues and the socket. This observation was confirmed in the present study on comparing films made with and without a contrast medium taken on the same patient, using the same X-ray settings for both series. With few exceptions, the contrast-medium films were superior to the routine films in outlining the periphery of the stump more sharply. An example of this superiority may be seen in comparing the two views in Figure 4. This improvement in the delineation of the stump-socket interface makes it easier to read the films and eliminates any doubts that may arise concerning the exact relationship between the stump and the socket at various stump levels.

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