

The UCLA Anatomical Hip Disarticulation Prosthesis

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This article discusses a new approach to hip disarticulation and hemipelvectomy fittings developed at the UCLA Prosthetics Education Program. It employs fundamental principles and methods in a new and different combination to produce a more complex and more natural biomechanical system. The results include:

- a smoother, and apparently less energy consuming gait
- improved stability
- improved suspension
- improved wearer comfort

Introduction

For several years now, the UCLA Prosthetics Education Program has been involved in an effort to understand, develop, and refine a teaching method for the CAT-CAM Socket,¹ the anatomically shaped above-knee socket. The very essence of this effort is a broader and more detailed understanding of the pelvic anatomy and its optimal containment within the socket. With the dramatic above-knee results that have been achieved through this understanding has come a compelling and obvious need to examine the application of the same principles to hip disarticulation fittings.

It was felt that a hip disarticulation socket design, which would encapsulate the ischium and ischial ramus in a more anatomical contour than previous socket designs, might produce an improved prosthetic fitting.² Since much of the CAT-CAM experience alluded to employed a frame supported flexible polyethylene socket,

the flexibility of such a design applied to a hip socket seemed a reasonable way to provide more comfort. These factors formed the basis for this work.

To date, three hip disarticulation patients and one complete hemipelvectomy patient have been successfully fit with the design described. The hemipelvectomy application followed the hip patient fittings by a number of months and was tried only as a whimsical experiment. Based upon the initial understanding of the biomechanics, this fitting was not expected to succeed. However, the results were quite surprising and motivated another look at the biomechanical analysis. Two of the hip cases and the hemipelvectomy case will be described in this article along with the biomechanics.

Patient Experience

The first hip disarticulation patient is a 23 year old male who had an amputation on the right side at age five for tumor, and who has rejected a prosthesis since age ten because it was too limiting and cumbersome. Owing to immature muscular and skeletal development at the time of amputation, he is significantly atrophied on the amputated side. This individual is extremely active, participates and excels in athletics as an equal with the able-bodied, and is impressively agile on crutches. Consequently, his remaining limb is hyperdeveloped to the extent that the thigh musculature extends well past the midline of the body.

The second hip case, a right amputee as



Figure 1. Posterior view of suspension system showing "X" pattern strapping.

well, could be described as a more typical patient. He is a 40 year old professional, amputated at age 28, also due to a tumor. He has worn a prosthesis continuously since his amputation, the most recent being an Otto Bock endoskeletal design. When this project was begun, he had recently taken delivery of a new one-piece flexible socket prosthesis which combined a Flex-Foot[®] with Otto Bock endoskeletal knee and hip components.

The hemipelvectomy case was a 26 year old male who had undergone complete amputation on the left side for a massive tumor in the hip joint. At the time of the work described here, which was six months post-surgery, he had not yet been fit for a definitive prosthesis, but was wearing a socket only for sitting comfort. This patient was first seen as a demonstration subject for prosthetic certificate students at UCLA. For that program, he was fit with a fairly conventional design. However, since his level of amputation is somewhat uncommon, and because the patient was willing to experiment, the design was altered to include the suspension system that had been found to be so successful with the hip disarticulation patients.

Fabrication

The hip patients were cast using a similar technique with splints, circular wrap, iliac crest



Figure 2. Anterior view of suspension system.

definition, anterior and posterior compression, and ischial weight-bearing while the plaster hardened. Since this was an attempt at a more anatomical socket, contours detailing the ischial ramus angle and the medial inclination of the ischium were included in the cast. Unlike the above-knee socket which flexes and extends with the femur through each stride, the hip socket is expected to remain relatively fixed, relative to the pelvic anatomy. Thus, the medial brim need not extend as high or contain as much of the ischial ramus. If properly executed, a cast which includes the bony contours of the pelvis will take much of the guesswork out of cast modification and fitting and should reduce the number of check sockets needed to attain an optimum result.

The initial concept for a hip disarticulation socket was a one-piece polyethylene design with a laminated frame to which the hip joint would be attached. Accordingly, such a system was fabricated for the first fitting. The results were reasonably successful. However, sound side comfort and piston action of the resulting prosthesis were not wholly satisfying. Since this was an experiment, it was decided to push further. Through several reiterations of socket size, volume and shape, and through several experiments with suspension, the design described in this article was arrived at: a two-piece system composed of a laminated anatomi-

cally shaped socket, encompassing only the amputated side and connected to a polyethylene suspension segment for the sound side waist with Dacron® webbing (Figure 1).

Fabrication of the socket for the hip patients was relatively simple because of the two-piece design. The original model was split and only the amputated side laminated. For the contralateral side, a shell of Aliplast®-lined polyethylene was vacuum formed over that half to serve as the suspension system.

Since the initial fitting of the hemipelvectomy patient was meant to instruct the certificate students in basic prosthetics for this level of amputation, the approach was very straightforward. He was cast in a suspended attitude with a simple circular wrap. Modification involved little more than smoothing of the model. A total flexible polyethylene socket was vacuum formed over the entire model. Following this, a frame for mounting the hip joint was laminated over the amputated side only of the polyethylene socket. As this was a demonstration fitting with no intent to finish, the hip joint was only temporarily attached.

Prostheses for all patients were assembled with Otto Bock endoskeletal 7E7 hip joints and 3R20/3R36 knee units. Several feet were experimented with on the first patient until an Otto Bock single axis foot proved optimum. The Flex-Foot™ that had been included with the second patient's recently delivered prosthesis was incorporated into his set-up. The hemipelvectomy patient was also fit with an Otto Bock single axis foot.

The socket and sound side suspension segment for the hip disarticulations were joined posteriorly with Dacron® webbing. Using temporarily attached four-bar buckles and the webbing, the proximal and distal aspects of the socket and the polyethylene segment were connected with the webbing to form an "X" pattern across the posterior gap (Figure 1). At their cross point, the straps are not connected but are allowed to freely move with respect to each other. The buckles were found to be necessary for "fine tuning" adjustments of the suspension during fitting and alignment. Anteriorly, a single strap attached at the distal aspect of the laminated socket was passed through a loop on the polyethylene portion and back to a roller buckle on the anterior proximal socket (Figure 2).

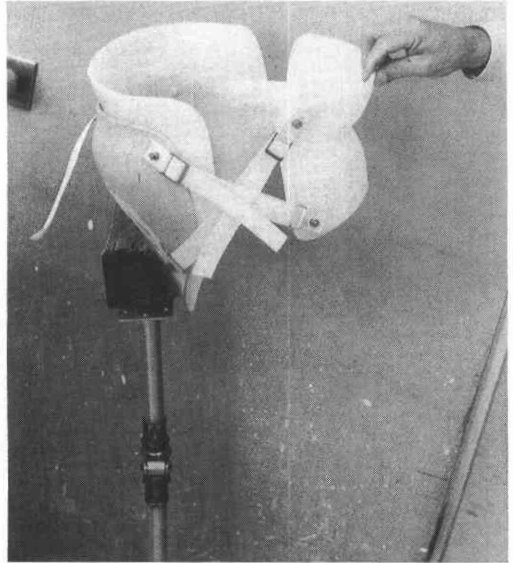


Figure 3. Posterior view of hemipelvectomy set-up showing adjustable cross strapping.

Functional Results

Results achieved with this combination of socket and suspension were dramatic. After some adjustments, the hip patients felt no discomfort from the socket, despite the obvious upward curve of the medial brim in the perineum. This edge, along with the distal portion of the socket, particularly under the ischium, were lightly padded with 1/8" Pe-Lite™, as is customary in most hip sockets. Neither patient perceived any piston action or discomfort from the proximal brim of the socket or the polyethylene waist segment. The most obvious benefit was a significant reduction in lateral trunk bending that is so common with hip disarticulation amputees. In fact, this gait anomaly was reduced beyond that usually seen with many above-knee amputees. Both patients were impressed with the comfort and secure feeling that the design afforded.

With the adjustable diagonal posterior straps, which in the finished prosthesis are replaced with buckleless double Dacron® webbing, the socket can be optimally positioned under the pelvis to more effectively encapsulate the bony pelvic anatomy. This is somewhat akin to adducting an above-knee socket of similar medial brim design (CAT-CAM). By a careful balance

in the strap length adjustments, comfort and suspension in the entire system can be achieved.

Because of the success that had been achieved with the hip disarticulation patients with this suspension technique, it was decided to try it on the hemipelvectomy patient. His reasonably comfortable and functional single piece socket was modified by removing the center portion of polyethylene in the posterior and rejoining the two separate segments with Dacron® webbing in the same cross strap pattern. An anterior closure as previously described was also employed (Figure 3). The result was about $\frac{1}{8}$ " of piston action and improved comfort over the one-piece design, probably because the prosthetic socket could more accurately follow the body contours.

Biomechanics

In all cases, it appears that during the gait cycle the polyethylene segment that encompasses the contralateral hip will tilt from the vertical as it follows the changing sound side body contour. The forces thus imposed on each of the posterior straps will vary alternately, and their crosspoint will shift slightly with each stride. For example, as the amputee reaches heel strike on the prosthesis, tension in the strap originating at the posterior proximal socket (the lateral support strap) will build as the body moves forward, and the center of gravity begins to shift laterally. As the patient progresses, this force reaches its maximum at mid-stance (Figure 4) and then begins to fall off. Tension in the other (suspension strap) is at its lowest at mid-stance on the prosthetic side and then begins to build toward its peak when the amputee reaches mid swing-through (Figure 5). The cycle then repeats itself with each successive stride. This alternating action in the straps, coupled with an accurately contoured socket, provides a continuously snug and secure suspension without the need for excessive tightness.

At the outset of these efforts, it was believed that much of the success of the suspension system depended upon a well-contoured medial brim, which accurately encapsulated the ischium and ischial ramus. The hemipelvectomy fitting quickly dispelled this consideration as a

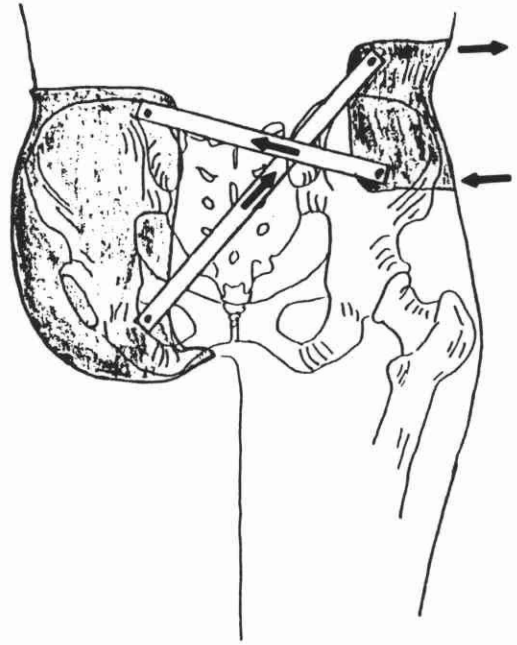


Figure 4. Suspension system forces at mid-stance.

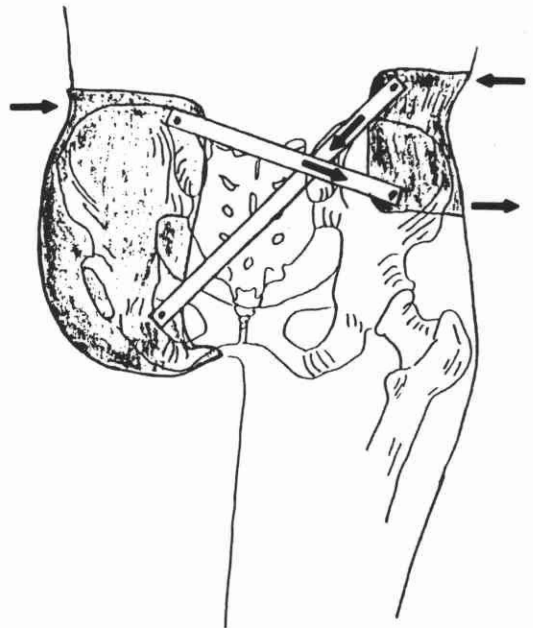


Figure 5. Suspension system forces during swing.

major factor. However, all hip disarticulation patients fit to date have perceived far greater comfort and control when in a socket so described. The idea behind ischial containment is to provide greater mediolateral stability in the prosthesis. It appears that the cross strap suspension is contributing the better part of this stability.

Results to date suggest that the two-part socket and posterior cross strapping provide a mechanism which more closely conforms to changing soft tissue and muscle contours through the gait cycle. With a one-piece socket, regardless of flexibility, slight and subtle motions about all three body axes are not fully accommodated by "give" in the socket, as well as they seem to be in the one described here. Thus, the body must either move inside the socket or limit its movements due to the restrictions imposed by the rigidity of the socket. In either case, the result is a less natural gait and a greater apparent expenditure of energy. With this new approach, these shortcomings of the hip and hemipelvectomy fittings seem to be significantly reduced.

References

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² Sabolich, John and Tom Guth, "CAT-CAM Innovations," *Ability*, Vol. 6, No. 3, Winter, 1986, p. 48.

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