Orthotics and Prosthetics, Vol. 39, No. 4, pp. 16–20.

The Application of ISNY Principles to the Below-Elbow Prosthesis*

Norman Berger, M.S.
Sidney Fishman, Ph.D.
David Krebs, M.A.
William Webb, B.S.

Since January, 1984, when New York University Post-Graduate Medical School introduced the ISNY (Icelandic-Swedish-New York) Above-Knee Socket System to the prosthetic profession by offering the first instructional course on this subject, this revolutionary technique has spread with surprising speed all over the United States and, indeed, through many of the industrialized nations of the world.[1,2] In view of the overwhelmingly favorable response to the comfort provided by the thinner, lighter, cooler, flexible ISNY socket and its weight-transmitting frame, it is obvious that consideration would soon be given to the application of these design principles to other amputation levels. The purpose of this paper is to report on the ISNY Flexible-Hinge Prosthesis, for the medium and long below-elbow amputee.

For this level of below-elbow amputee, the conventional prosthesis is fabricated of rigid plastic laminate, with a double wall construction. The inner wall forms the socket and the outer wall provides for attachment of the wrist unit and flexible hinges, as well as for appropriate length and shape. As illustrated in Figure 1, the ISNY below-elbow prosthesis consists of a thin, thermoplastic socket connected via volar and dorsal struts to the laminated distal portion. As in the above-knee ISNY design, the socket is soft and flexible rather than hard and rigid. The frame, while allowing for length, shape, and component attachment, is minimal in size and extent.

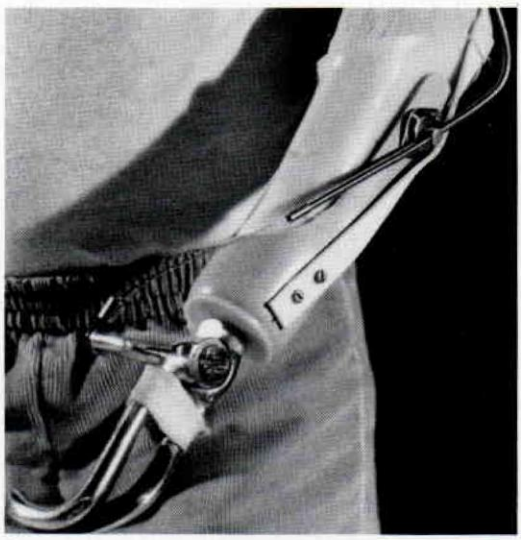

Figure 1. I.S.N.Y. Flexible Hinge Below-Elbow Prosthesis.

*Funded by Special Project MCJ-363082—Bureau of Health Care Delivery & Assistance Division of Maternal & Child Health, U.S. Public Health Service, Rockville, MD 20857.

Characteristics of Sample

Subject	Age at Fitting (yr.)	Sex	Length as Compared to Sound Side (%)	Duration of ISNY Experience (mo.)	Weight Difference (Conventional-ISNY Forearm) (oz.)
1	11	M	62	2	6.25
2	18	F	69	7	4.0
3	13	F	38	7	4.0
4	13.5	F	69	7	5.5
5	14	F	75	11	4.75
6	7.5	M	68	2	4.0
x	12.8	4-F, 2-M	63.5	5.8	4.75

Table 1.

CLINICAL EXPERIENCE

Following several laboratory fittings for developmental purposes, the first ISNY below-elbow prosthesis was delivered in February, 1984 to a 73 year old male, semi-retired plumber who had been a part-time user of his conventional prosthesis. With the ISNY prosthesis, however, he became a full-time wearer, and was able to perform his activities of daily living and vocational activities more comfortably. The subject has worn the ISNY prosthesis successfully for more than one year without need for repair. Due to these encouraging reactions, NYU began a series of ISNY flexible-hinge below-elbow prosthesis fittings to a group of young amputees, this being the specific population that we were funded to serve.

In our initial series, six unilateral, congenital, below-elbow amputees were fitted. The four girls and two boys range in age from 7½ to 18 years (X = 12.8 yrs.), with an average residual limb measuring 63 percent of sound forearm length. All were full-time wearers of conventional prostheses. ISNY sockets were fabricated for each subject utilizing a new plaster negative impression, plaster positive model, and wrist unit, but the terminal device and harness type were unchanged. These six individuals have worn the new sockets for an average of 5.8 months (range: 2-11 mo.). The forearms containing the ISNY sockets have averaged 4.8 oz. lighter than their conventional counterparts (Table 1).

Structured interviews were conducted with each wearer at the time of delivery of the new prosthesis and at two, four, and six week intervals post-delivery to elicit comparative opinions concerning the conventional and ISNY prosthesis. As detailed in Table 2, all subjects indicated that the ISNY was more comfortable than the conventional socket, being lighter, cooler and permitting the input of sensory stimuli, particularly when writing or leaning on the prosthesis. They also reported that wear times increased with the ISNY system, especially during the summer months, and that the device "felt more like my real arm," probably due to the greater intimacy of fit made possible by the soft, flexible thermoplastic. Three individuals objected to the appearance of the prosthesis, indicating that the two dissimilarly colored parts

Comments Regarding the ISNY Below-Elbow Socket

Comment	Number of Children
Comfort	
Lighter	6
Adheres to limb better	5
Able to wear most of time	5
Cooler	5
Softer	2
Better flexibility	2
Feels more like part of my arm	2
Thinness is good	2
Heat: same	1
Good pressure distribution	1
Sensation	
Better feedback from environment	5
Better sensation	4
Quieter when ISNY strikes something	3
Likes to touch ISNY	2
Friends like to touch ISNY	1
Hurts others less when they are struck	1
Function	
Better pro/supination	3
Better flexion ROM	2
Hook opens more easily	1
Doesn't slip off table	1
Appearance	
Appearance better	3
Appearance worse	3

Table 2.

(socket and frame) "looked different than a real arm." Nonetheless, they persisted in wearing the device due to the overriding comfort and other advantages in comparison with the conventional system. The other three individuals considered the cosmesis to be better than the conventional.

In summary, all subjects reacted enthusiastically to the new sockets and emphatically rejected any suggestion to return to their conventional sockets.

FABRICATION METHODS

Vacuum-forming the Socket

Using round frames (inside diameter 9") and a round platen (diameter 8"), the socket is vacuum formed from either polyethylene or Surlyn.® For longer and broader residual limbs, the thermoplastic should be 3/16" thick, while for shorter and thinner residual limbs, 1/8" thickness may be used. In most cases, drawing the socket over the plaster model is a simple and straight-forward procedure.

Problems may be encountered, however, if the residual limb presents an unusual non-conical shape, as for example a wrist disarticulation with undercuts just above the styloid processes, or a limb with a distinct curve at its end. It is difficult to prevent wrinkling and excessive thinning of the socket wall in these undercut areas. To solve such problems, we have either used 1/8" Surlyn,® which tends to mold more easily than polypropylene; or 1/4" polyethylene, in which case the portions of the socket that are too thick are ground down and buffed to appropriate thinness and flexibility. This latter solution does not work with Surlyn® because it does not readily accept grinding.

Frame Lay-Up

With the socket, the wax extension, and the wrist unit in place on the plaster positive model, lay-up materials are applied as follows:

- a sleeve of light dacron felt
- two layers of nylon stockinette
- two layers of carbon fiber tape(1/2" width) placed along with volar and dorsal midlines of the socket and extension
- two layers of nylon stockinette

With the exception of the carbon fiber, all materials are pulled over the model and tied off at the wrist unit in the usual manner. The layers of carbon fiber tape are formed by folding a one inch width lengthwise, thus creating two layers of 1/2" width, and sewing to maintain the fold. These sewn lengths are then placed along the volar and dorsal midlines beginning approximately one inch proximal to the

wrist unit and extending to approximately one inch distal to the anticipated socket trimline.

Frame Trim

After lamination, the frame is trimmed so that the volar and dorsal struts are approximately ¾" in width, which means that about ⅛" of resin-impregnated nylon and dacron felt remain on each side of the ½" wide carbon-fiber tape. Proximally, these struts terminate anywhere between ⅛" and ¾" distal to the socket trimline. The shorter the residual limb, the closer the proximal termination will be to the socket trimline.

Posteriorly, the curve which connects the struts is at a level just distal to the distal end of the residual limb. Anteriorly, however, this curve is just proximal to the distal end of the residual limb (Figure 2). The purpose of the more proximal location of the anterior curve is to improve cosmesis by hiding the site of amputation, without contacting the socket. It is essential to keep this in mind when preparing the wax forearm extension, which must be shaped so as to provide approximately ⅛" clearance between socket and frame in this area.

Attachment of Socket to Frame

Several methods of attaching the socket to the struts have been explored. Our initial approach of simply riveting the thermoplastic socket to the frame resulted in bearing failure due to the inadequate area available to resist stress. As a second approach, the socket was formed over Nyloplex strips placed on the volar and dorsal sides of the positive model with Nyloplex rivets put through the socket, frame, and strips. This greatly increased bearing surface solved the bearing failure problem, however, fabrication proved to be a somewhat cumbersome and time-consuming process.

The preferred procedure utilizes an adhesive-backed, Velcro type** pile secured to the thermoplastic socket, with the hook

Figure 2. I.S.N.Y. flexible socket displaying anterior distal trimline.

portion either adhesive backed, or glued to both struts with Devcon 5-Minute Epoxy® or 3M#4693.® The parts are then simply pressed together. Although this technique provides a very satisfactory attachment, the mediolateral dimension of the prosthesis is increased by the thickness of the pile and hook. It is possible, if desired, to reduce this dimension by utilizing only the pile. As before, the adhesive backing of the pile is applied to the thermoplastic socket; however, the other surface is glued directly onto the laminated struts.

Harness Attachment

The flexible hinges are attached to the ISNY forearm at the conventional sites. However, it is important to recall that the cross-hanger strap that connects the two hinges should be positioned precisely at the joint centers (i.e., directly over the humeral condyles).

Though we are unable, as yet, to report long-term results on a large number of patients, we are confident on the basis of the evidence presented that the ISNY Flexible Hinge Prosthesis, as described, represents a significant advance in prosthetic comfort and function for medium and long below-elbow amputees. We are also confident that the same approach will be applicable to

**Scotchmate Hook and Loop, 3M Manufacturing Co., Minneapolis, Minnesota.

other types of lower and upper-limb prostheses and we are currently directing research efforts along these lines.

REFERENCES

[1]Kristinsson, O., "Flexible Above Knee Socket Made From Low Density Polyethylene, Suspended By a Weight Transmitting Frame," *Orthotics and Prosthetics*, Vol. 37, No. 2, pp. 25–27, 1983.

[2]Faculty, Prosthetics and Orthotics, New York University Post-Graduate Medical School, New York, New York, Fabrication Procedures for the ISNY Above Knee Flexible Socket, April 1984.

[3]Faculty, Prosthetics and Orthotics, New York University Post-Graduate Medical School, New York, New York, Upper-Limb Prosthetics-Prosthetists Supplement, 1982 Revision.