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Technical Note: An Alternative Design for a High Performance Below-Elbow Prosthesis

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INTRODUCTION

Upper extremity prosthetic design for below-elbow amputees has continually evolved in an attempt to improve suspension and comfort without sacrificing range of movement and function. The advent of electro-mechanical (myo-electric) prostheses which do not require harnesses has led to improved "Muenster" style socket type suspension systems which can be applied to conventional prostheses as well.[1] The development of lower-extremity flexible socket systems also opens up some intriguing possibilities for upper extremity prostheses at the same time.[2] New materials are constantly evolving, which also lead to improved socket technology and fabrication techniques.

CASE STUDY

The project began as an effort to construct a relatively lightweight, strong, below-elbow prosthesis with a high comfort range, specifically designed to function with a GRIP[3] voluntary closing terminal device system. The amputee was an experienced prosthesis user, for more than 13 years, with a four inch, below-elbow amputation. This patient pursued a variety of rigorous activities which required bilateral strength and coordination. Past hard socket prostheses, with varying designs and styles, had not provided a sufficient range of comfort to protect the bony prominences of his residual limb. The condyles, olecranon, and the distal end of the residual limb suffered constant stress and aggravation resulting in redness, soreness, and tissue degradation during rigorous activities.

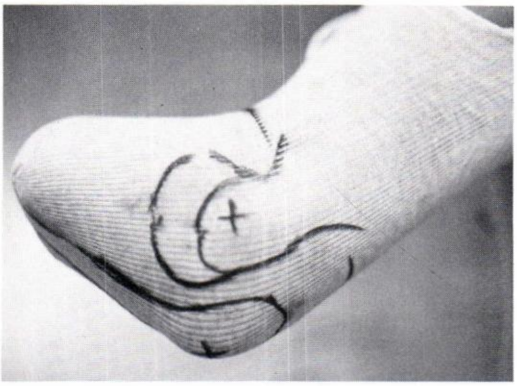

Figure 1. Outlines for bony prominences.

Figure 2. Note the markings around the condyles and distal end of the ulna and radius.

Prior to fabrication, a full socket liner concept was considered but rejected because of the heat build up and anticipated increased perspiration. The chosen design was a two-piece partial liner which used padding to protect the distal end, condyles, and olecranon.

MEASUREMENT AND FABRICATION

While outlining bony prominences for the cast (Figure 1), the prosthetist paid special attention to the sensitive areas around the condyles and distal end of the ulna and radius (Figure 2) because of the high forces generated by the amputee's activities. "Muenster" type socket casting and modifications were used, and a check socket made of rigid acrylic resin was fabricated.

During positive model modification, large reliefs were provided for the biceps tendon in order to achieve full flexion. The posterior brim was extended proximally to spread out the otherwise concentrated forces proximal to the condyles during full extension of the prosthesis. The amputee found this modification necessary to avoid tissue breakdown during rigorous activities, such as weight lifting and rock climbing. The check socket was adjusted to create as much tension as possible on soft tissues, to achieve better prosthetic control and improve proprioception.

With the elbow extended, pushing the arm into the check socket yielded very little tissue displacement. However, the distal ends of the ulna and radius came into slight contact with the distal end of the socket. At this point, the location of the distal and proximal pad for the condyles and olecranon was outlined, after which the socket was bivalved, and outlines for the pads were transferred to the positive mold.

After considering and trying a variety of materials for the pads,[4] Pelite® was chosen because of its simplicity, durability, and cleanliness. The Pelite® was formed and trimmed to fit within the bony outlines. With the pads in place (Figure 3), the definitive socket was laminated, after which the positive model was broken out and the pads saved. Foam was then applied pre-extending the socket three to five degrees, and cut to length. The socket was refitted and the patient put it through some light-weight maneuvers, at which time an optimum alignment was found.

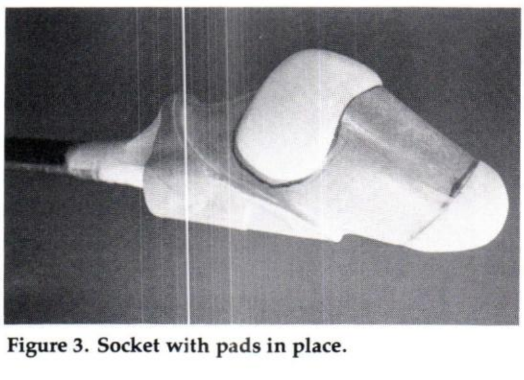

Figure 3. Socket with pads in place.

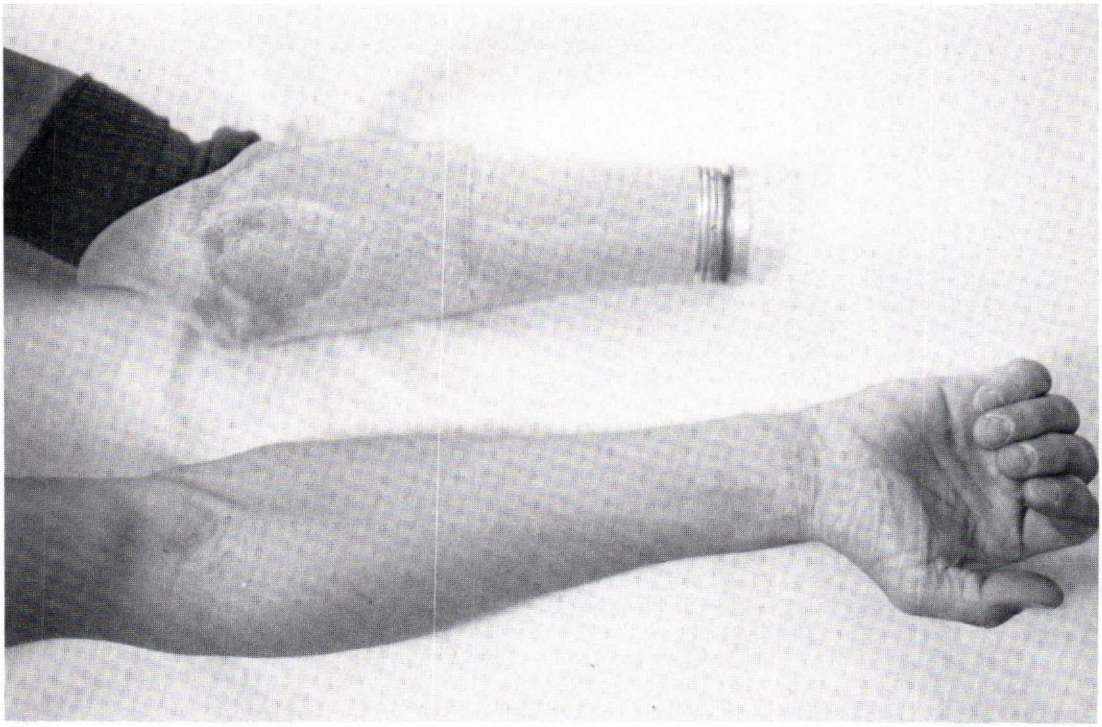

Figure 4. Comparing forearm socket with patient's sound extremity.

The foam was shaped to match the patient's sound forearm (Figure 4). The color of the resin was matched to the patient's skin pigment, and carbon fiber and acrylic resins were used in the lay-up to increase strength.

RESULTS

After approximately one month of use, the distal end pad of Pelite® was replaced with a "T" foam insert for more cushioning. The primary Pelite® pad, which protected the condyles and olecranon, was modified. Modification involved slightly extending the pad edges proximally at the condyles and olecranon while correspondingly relieving the socket to accept the larger pad. The modification proved successful and satisfied the patient's needs.

Almost a year later, the patient reports that heat and perspiration factors are comparable to a hard socket. The patient's residual limb has remained in excellent condition since the fitting and he does not experience the negative effects that were induced with a hard socket.

The final design resulted in a prosthesis (Figures 5 & 6) which required no break-in period and was reported as "the most comfortable prosthesis" that the patient had ever worn. To date, the prosthesis has been exposed to such activities as mountaineering (including technical rock climbing), windsurfing, and both snow and waterskiing, with excellent results. The padding has also provided a form of thermal insulation for additional cold weather comfort.

Some unusual aspects of this prosthesis need to be emphasized. First, the socket is designed to be pre-extended, not preflexed, allowing total arm extension. This design limits flexion of the prosthesis to within five inches of the face, but is preferred by the patient, who is a unilateral amputee. The extended posterior brim at the rear of the socket distributes distal prosthetic loads to the back of the humerous and removes the load from the distal

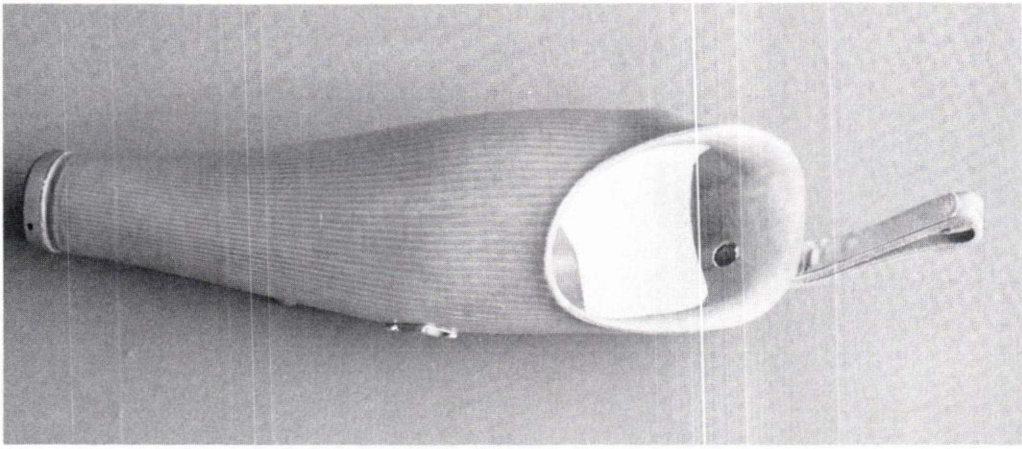

Figure 5. Finished prosthesis.

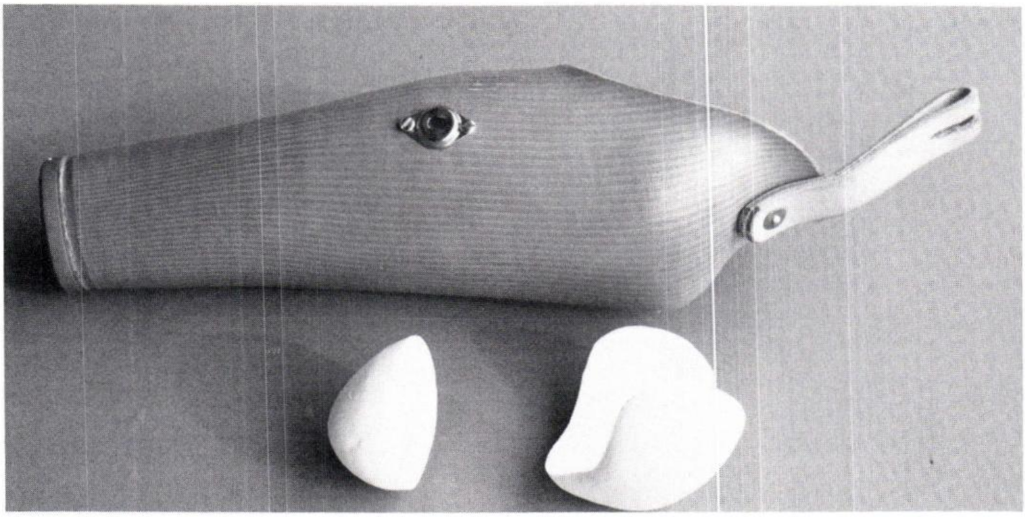

Figure 6. Finished prosthesis and pads.

end of the residual limb. This cantilever effect allows for the handling of heavy loads with a short limb and relieves the pain usually associated with loads applied to the distal end of the prosthesis. The prosthesis' length was aligned to finger tips and not the thumb of the patient's sound hand. This was preferred even though the residual limb is only four inches below the elbow.

Finally, the harness is extremely simple but very effective. A triceps cuff is not present, and the design utilizes a modified Northwestern Figure 9 harness. A ring and rapid adjust buckle are used to adjust cable excursion three to four inches, which can enhance the use of voluntary closing terminal device systems.[5] A leather cross bar strap is riveted to the back of the socket, and supports the cable, keeping it off the triceps area. Interference with dress shirts is not apparent (Figure 7). The harness rides low across the back, but can be slipped up over the shoulder for improved range holding above the head. With amputees rejecting conventional prostheses due to the complex harness systems (such as Figure 8 harnesses), this design offers a much less cumbersome, comfortable, yet very functional, alternative.

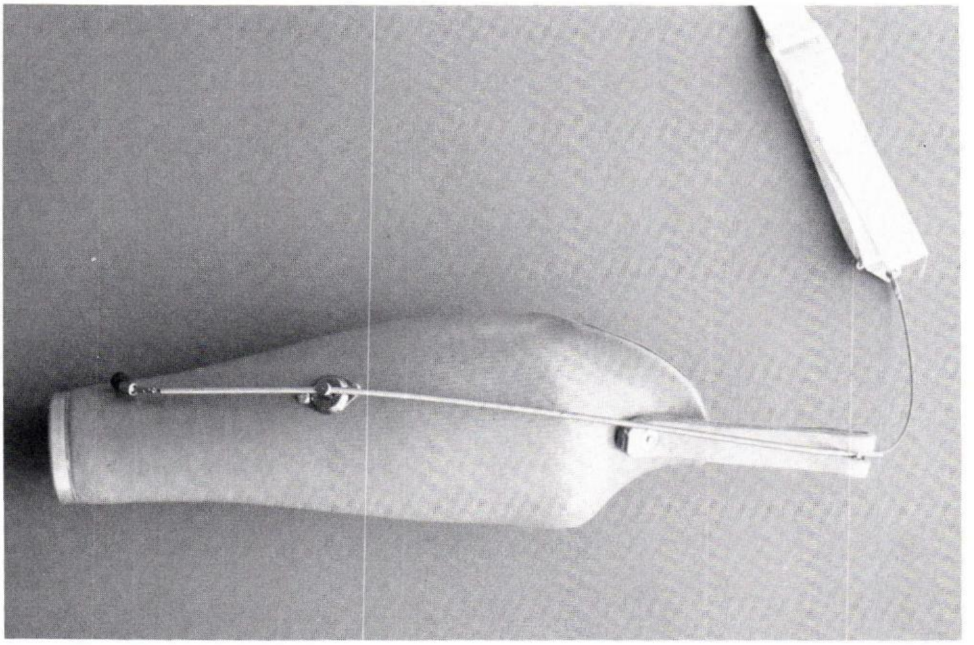

Figure 7. Prosthesis with cable attachment.

CONCLUSION

It is the authors' contention that this prosthetic design is a viable alternative for the active below elbow amputee with a short to mid-forearm limb absence. The self suspending socket design, when it can be tolerated, reduces cumbersome harnessing, allowing for the application of simple, efficient, lightweight cable control systems. The added comfort and simplicity can only encourage more active use of the prosthesis, a primary rehabilitation goal.

AUTHORS

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[2]Fornuff, D.L., C.P., "Flex-Frame Sockets in Upper Extremity Prosthetics," *Clinical Prosthetics and Orthotics*, Vol. 9, No. 4, pp. 31–34, Fall, 1985.

[3]Trade name for terminal device from T.R.S., Inc. of Boulder, Colorado.

[4]Dow Corning Silicone Prosthetic Foam; Action Products, Inc., Acton and Zekon.

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