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Voluntary Closing Control: A Successful New Design Approach to an Old Concept

by Bob Radocy, M.S.T.R.

The arrival in early 1980 of the "Prehensile Hand,"[1] a new design and concept for terminal devices, sparked a revitalized interest in body power and voluntary closing control. Voluntary closing control and terminal devices are not new to prosthetics, but little interest in this system and technology has existed since the 1950's. Retrospectively, voluntary closing control never achieved dramatic success nor did it have any permanent, positive influence on the direction of upper-extremity prosthetic development until recently, meaning 1980–1985.

The acceptance and success of the "GRIP,"[2] (Figure 1) and more recently the children's "ADEPT"[3] terminal devices, are strong indicators that voluntary closing control is an extremely viable concept. Furthermore, it confirms previous opinions that poor performance characteristics, reliability factors, and the inappropriate design criteria of early volunteer closing control systems and terminal devices[4] were responsible for the demise of voluntary closing systems and correspondingly for the dominance of voluntary "opening" control systems and terminal devices in the profession today.

This is not to say that voluntary closing devices and systems were not put to excellent use by certain amputees, but that they failed to appeal to the majority of the upper-extremity limb deficient population, i.e. the traumatic or congenitally limb deficient below-elbow unilateral amputee.

The standard voluntary opening split hook has continued to be the primary body-powered prescription, while experience now strongly il-

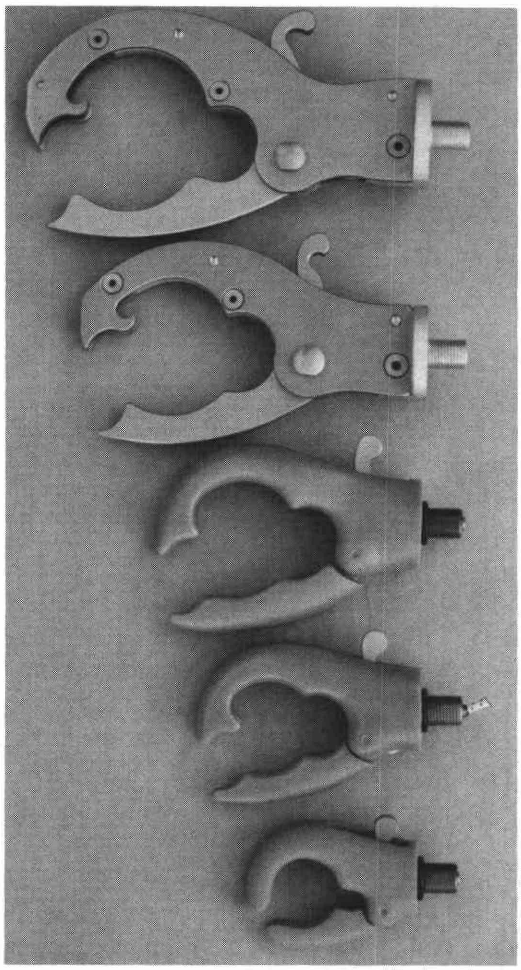

Figure 1. (Top to bottom) GRIP I, GRIP II, ADEPT B, ADEPT C, and ADEPT I.

lustrates that correctly designed voluntary closing terminal devices offer superior performance to the limb deficient. Training is no more difficult with voluntary closing; gripping force range is expanded and directly proportional to output, reflex grasping actions are improved, muscles of the affected limb and shoulder are utilized continuously and more effectively, and "feedback" sensations (Figure 2) are produced inherently† and are more easily assimilated, thereby enhancing control, than in voluntary opening systems.

The mere fact that children three to six years of age have accepted the concept and have either learned with or converted to voluntary closing control and achieved good to excellent performance should open the minds of even the most conservative in our profession as to the value of the voluntary closing control prescription.

Recently, we have seen and heard a great deal about the success of myoelectric devices for children and how a child's performance is improved with myoelectric systems as compared to "body-powered" systems.[5] Unfortunately, body power in these comparisons refers only to the voluntary opening split hook systems, and not to voluntary closing systems. It is my firm belief that, if given proper training, limb deficient children will perform as well or better with voluntary closing body powered systems than with myoelectric systems. Furthermore, considering the cost and reliability of externally powered limbs, voluntary closing body powered terminal devices should be prescribed as the primary complements to external powered units, rather than voluntary opening split hook systems.

The logic for this assertion is simple. First, muscles of the torso and limb are used more actively with the voluntary closing system, and healthy, strong muscles can only enhance externally powered control and utilization. Second, the new designs in voluntary closing terminal devices offer an opposed thumb and finger gripping configuration, similar to powered hands, enabling the user to incorporate already "learned" patterns of gripping behavior, rather than having to constantly switch patterns of grasp to accommodate "split hook" prehension. Third, children with voluntary closing systems can achieve gripping prehension which equals or exceeds their anatomical capabilities, while voluntary opening systems remain inferior in this area. Comparable prehension bilaterally can only encourage bilateral function and increase prosthetic usage, two primary goals in prosthetic rehabilitation.

The success of voluntary closing systems can be related to the design rationale and criteria of the 80's systems. Rationale and criteria are as follows:

† A major objective of externally powered systems is to develop a reliable "feedback" system for improved prehension control. Voluntary closing, body-powered systems offer the feedback system inherent in the design.

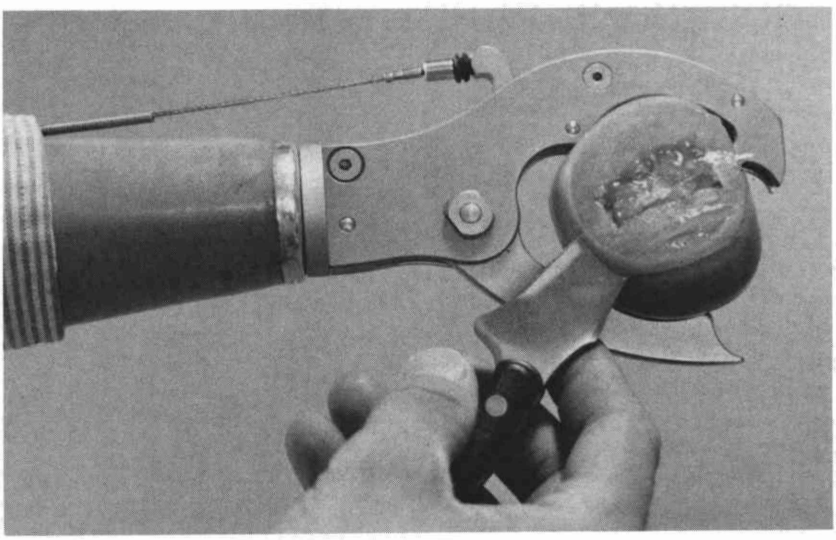

Figure 2.

1) Utilize an accepted natural prehension configuration. Previous studies indicate that cylindrical, palmar, and lateral are the most often used gripping patterns.[6] Opposed thumb and forefinger prehension satisfies these patterns.
2) Design gripping shapes and surfaces to allow for a wide variety of holding tasks. Complementary curved gripping surfaces enhance cylindrical control and are especially important due to the vast numbers of curved object surfaces we handle daily (Figure 3). Additionally, a "clevis" tip configuration imitates the three point chuck of the thumb, index and long finger, important for utensil and implement control (Figure 4).
3) Emphasize a simple, anesthetic, easily maintained, reliable design that can be understood and accepted by the user— a design with positive psychological connotations, reflecting the capability of the user.
4) Incorporate passive support and suspension capacity (internal hook or bump) for carrying objects with handles or for supporting body weight while climbing or hanging.
5) Require continuous control for grasping and holding to discourage muscle atrophy, enhance muscle development and allow for rapid reflexive grasping. Continuous control also creates an uninterrupted flow of pressure feedback information required for performance handling of objects.
6) Select materials suitable for individualized age groups, rather than a single material for all models. Consider both the needs and the characteristics required for each population and design the model accordingly for each targeted group.
7) Consider weight as a factor, but balance the need for light weight against the strength requirements for the terminal device. Also consider the tolerance the need for light weight against cause variation in age and corresponding tolerances vary.

Figure 3.

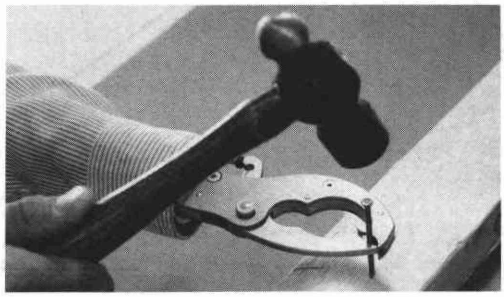

Figure 4.

8) Redesign models as necessary to better answer the needs of the population they serve.

Exclusive of these criteria, a variety of factors exist which have aided the reintroduction of voluntary closing systems and which will increase the use of these systems in the future. Compatibility, harnessing, prosthesis design, proper rehabilitation and weight conditioning are all important if good to excellent prosthetic use is to be achieved.

Voluntary closing terminal devices are compatible with all standard prosthetic components. Minor cable modifications or adjustments are usually required to optimize the user's energy output. Unlike previous voluntary closing designs, the user is harnessed under "controlled tension" rather than into a "no tension" system. Accordingly the thumb of the terminal device is not fully open, but pulled partially closed when the arms are relaxed at the user's sides. This tension harnessing allows for improved control of objects, during initial training, and while objects are manipulated close to the medial line of the body.

Harnessing should be as simple as possible. A modified Northwestern #9 when possible is excellent, utilizing a ring and "rapid adjust" type buckle.[7] This harness system will enhance range of motion control at the shoulder, improve object manipulation overhead, and enable quick excursion adjustments.

Prosthesis design should lean towards self suspending (supracondylar) sockets to minimize harnessing. Modified Muenster, Otto Bock, and similar designs can be employed depending on the limb's morphology. New designs such as ISNY or similar flexible sockets may also prove valuable. New patients should be educated in range of motion and pre-prosthetic exercise techniques.[8,9,10,11,12,13] This is especially important for traumatic limb loss and in instances where complete rehabilitation was lackingand the shoulder girdle and upper limb musculature is weak and atrophied. Similar atrophication can occur due to disuse of the prosthesis or lack of vigorous bilateral use.

Initially, muscle soreness at the shoulder may be experienced by the converting amputee, or the new amputee undergoing rehabilitation. This early soreness is a positive sign of muscle rejuvenation and should be regarded as improved health. However, long term muscle aggravation and soreness may be an indicator that the prosthetic system is not operating optimally.

Prior to prosthetic fitting and after initial rehabilitation with the new voluntary closing prosthesis, weight training can be encouraged. Pre-prosthetic training can be accomplished by a knowledgeable therapist and should include a range of motion exercises, dynamic tension, and active bilateral resistance exercises using cuff weights, specialized training equipment, or a simple weight harness in conjunction with dumbbells. Post-prosthetically, the voluntary closing terminal device is capable of handling adjustable resistive weight equipment or free weights, although the former are easier to use, safer, and enable rapid, satisfactory results. An emphasis on strength and endurance conditioning rather than muscle building is suggested due to the needs for adequate range of motion in prosthetic control. This dictates lower resistance loads with more repetitions of exercises.

Special applications for voluntary closing systems have also arisen in recent years. Brown[14] has achieved excellent success in patients with partial hand amputations. The success, I believe, is due to the common sense simplicity of the prosthesis and harness design, and the utility of the terminal device, which allows prehension in excess of 100 lbs. This amount of gripping force enables the partial hand amputee to be functionally bilateral in a manual working environment. Other terminal devices applied to the case of partial hand amputation cannot offer all the advantages of the new voluntary closingsystems. Obviously, the partial hand prosthetic user will not wear the prosthesis all the time, but it is an effective functional tool for many occupations. The increased potential may enable the partial hand amputee to maintain an existing vocation rather than consider retraining for an entirely new occupation.

In summary, the new voluntary closing systems offer a great deal of potential for the upper-extremity limb deficient of all ages. They can offer superior performance compared to any other systems, body powered or externally powered, and complement the externally powered prescription, when cosmesis is the primary consideration and function considered only of secondary importance.

Voluntary closing systems are not a cure-all for the upper limb deficient individual, and the system is not applicable to everyone, even though all types and levels of amputees including bilaterals have used the technology successfully (excluding shoulder disarticulates). Success also has a lot to do with the attitude of the amputee and the capability of the rehabilitation team, including the prosthetist.

Voluntary closing systems will continue to increase in popularity because the technology is reliable, improves performance, and more closely imitates the natural system.

The voluntary closing systems will also continue to improve as more innovative research and development in better "total" body powered and hybrid body powered/external powered prosthetic technology evolves.

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