GUEST EDITORIAL

Upper Extremity Amputation and Prosthetics

Nine years ago, this subject was discussed for the last time in the journal *Medizinisch-Orthopädische Technik* (1). Five years later, Baumgartner and Botta compiled their personal experience of over 30 years in a textbook on "Upper Extremity Amputation and Prosthetics" (2). Fortunately, upper extremity amputations are about 20 times less frequent than are those of the lower extremity. However, for every amputee and his or her family, the loss of the upper extremity, total or partial, is a much more severe disaster than the loss of the lower one. Apart from the face, a hand is the most individual and personal part of the human being. Not only the fingerprints but also the size, the shape, and particularly the gestures of the hand are extremely specific for every person. The German philosopher Kant even observed, "the hand is an extension of the human brain." Last but not least, the amputation of a hand was a method of punishment in medieval Europe. It still is practiced in certain Islamic countries and also became a horrible weapon of terrorism (3).

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Limits to Prosthetics

Prosthetic technology does its best to minimize the damage already done. In upper extremity prosthetic replacement, however, the gap between what the amputee desires and the replacement received is more evident than with any other prosthetic device. And the discrepancy becomes worse with every higher level of amputation. The need for prosthetic replacement is greatest in bilateral amputees who have lost their elbows. But in this situation, the most sophisticated prosthetic replacement is unable to make these amputees fully independent of a third person, particularly in such daily activities where no one likes to be helped, such as in personal hygiene, in feeding, and in writing. Technical aids for daily living and professional activities become more important contributions to the quality of life than prosthetic replacements. Driving a car has been made possible even for armless people through the efforts of Ernst Marquardt and Eberhard Franz in Germany (4).

Rehabilitation Results First Depend on Amputation Level

Surgery begins with the selection of the level of amputation. The surgeon in charge bears the full responsibility for selecting the

most peripheral possible amputation level while still creating a stump that is free of pain and is functional with or without a prosthesis. A better solution would be for the surgeon to succeed in saving his patient from an amputation, but with a good result that is functional and free from pain. The challenge of a replantation of an amputated extremity also has to be considered, particularly in finger reattachments.

In amputation-level selection, every single centimeter of length deserves to be considered. The advantage of a short carpal stump *versus* a wrist disarticulation cannot be overestimated. The same is true for wrist disarticulation *versus* transradial amputation, for the ultrashort transradial stump *versus* elbow disarticulation, from elbow disarticulation to transhumeral amputation, and so on up to the forequarter.

For example, in wrist disarticulation *versus* transradial amputation, the fully preserved length of forearm offers the amputee a full range of pro/supination. A long lever and a bulbous shape of the stump would permit an excellent prosthetic attachment without covering the elbow and thus limiting pro/supination. However, wrist disarticulation cannot be recommended in patients with arterial occlusive diseases. This means that in amputation-level selection, the etiology must also be considered.

The well-known prosthetists' objection that a prosthetic fitting of ultralong and ultrashort stumps does not give satisfactory functional and cosmetic result has not been valid for at least the last 30 years. Silicon techniques, as first developed by the dentist Pillet in Paris (5), provide a full but nevertheless comfortable contact between the stump and the socket without any free play. This facilitates prosthetic handling and also promotes indirect proprioception. Modern prosthetic components do not create an overlength of the hand replacement even in myoelectric fitting. But in wrist disarticulation, the surgeon must be aware of the importance to remove only partially, but never totally, the styloid processes and to cover the stump end with an asymmetrical palmar flap of full-thickness skin so as to facilitate the socket fitting.

Special Surgical Techniques

In surgery, special amputation techniques are well established. Two of the best go back as far as World War I (WWI), in 1917. One of the techniques is called the Krukenberg's procedure. In transradial amputees, Krukenberg divided the ulna and radius to form a sort of chopsticks, which restore grip function with full sensation in an amazing way. There is still nothing better than Krukenberg's technique in bilateral blind amputees, mostly victims who have had explosives blast in their hands. Krukenberg's procedure also represents the only way of improving life in the estimated 10,000 amputees in Sierra Leone, mostly females and children, who had their hands chopped off by terrorist rebels in the year 2000 (6). The same procedure was adopted 40 years ago in Bangladesh and honored with a postage stamp in the year of the disabled person (7).

The second technique is cineplasty, developed by Sauerbruch during WWI in Zurich and later on in Berlin. With Lebsche's modification of tunneling the biceps muscle in transradial amputees, the amputee is able to operate the prosthetic hand with an excellent sensory feedback. Even in the area of myoelectrics, Brückner in Germany proved the value of this technique. Surprisingly enough, none of his patients complains of phantom pain (8,9).

There are many more surgical techniques for better stump quality and easier and safer prosthetic fitting. They all are worthwhile to be discussed, before, during, or after prosthetic manufacturing and training. Therefore, they must be included in the training program of surgeons in charge of limb amputation, rehabilitation medicine specialists, prosthetists, occupational therapists, and other health professionals as well. The need for an interdisciplinary approach is evident (10). If only it were not that difficult to realize in our everyday work!

The Importance of Sensory Feedback

It is understandable that in upper extremity prosthetics, function and cosmesis are given priority. But sensory feedback is just as important. It is at its best if no intermediate prosthesis exists, as in patients who prefer not to use a

prosthesis at all, including the Krukenberg "hand."

The second best solution is a body-powered system. The tension of the body harness or the stirrup in the cineplastic tunnel gives the amputee excellent information about what is happening in his prosthetic hand or hook.

Myoelectric systems lack this kind of feedback. The amputee must refer to acoustic and, above all, visual feedback. In the dark or with impaired view and audition, the amputee will be lost. Therefore, one can only hope that the importance of direct or indirect sensory feedback should not be forgotten with all the progress being made in myoelectrical systems.

Evidently, there is an urgent need to modernize the concept of cineplasty. The research work performed by Weir and Childress at Northwestern University of Chicago (11) and Brückner in Germany (8,9) will hopefully open the door for the revival and better acceptance of the concept of cineplasty.

Socket Design and Material

Regardless of the prosthetic system prescribed for a patient, the socket shape and material are just as important as the prosthetic components themselves. Socket systems for transradial or transhumeral amputees that do not restrain the range of motion of the elbow and shoulder joints and still provide safe suspension and excellent comfort are a great progress in prosthetic technology. Silicon techniques make this possible, just as in the tremendous progress achieved in better cosmesis of prosthetic hands.

Limits to Surgery

But what about the insertion of titanium screws that extend beyond the ends of the ulna and the radius in order to click on a prosthesis as in clamping boots on to skis? The idea is almost one hundred years old. What has been presented so far as a breakthrough in stump surgery and prosthetics has been sooner or later abandoned because bacteria just love to take this path into a bone, which then becomes not only infected but also osteoporotic because the screws relieve it of mechanical strain.

Actually, a surgeon is promoting this idea again with a more sophisticated system named "osseointegration." And the orthopedic industry is looking forward to being ready with the proper attachment once this procedure has become generally accepted. It will probably take more years than before for this system to be abandoned because of infection, loosening of the screws, and fractures. Eventually, it will result in shortening of the stumps in young amputees who will be perhaps 30 to 40 years of age by then (12).

Another more off-limits procedure is the temptation of a *hand transplantation* to restore not only natural function and cosmesis but also body integrity. This dream is as old as humanity. To date, only one successful case has been reported. It was performed centuries ago by two saints, Cosmas and Damian, who succeeded in transplanting a leg of a corpse to an amputee, apparently with brilliant success, as far as the immediate result was concerned. There is no information available about the long-term outcome (13).

But almost 2,000 years later, medicine has started the race for the first successful hand transplantation. There is no objection with regard to the surgical technique. There is some objection about the immunological problems that arise with the transplantation of a foreign body, this necessitating the life-long use of immunodepressives with all the ugly side effects. But above all, the transplanted hand represents a foreign body from a foreign, unknown person. The amputee becomes a "transplantee" who is constantly busy caring for that masterpiece of microsurgery and getting along with it. And if he or she wants to rid him- or herself of it, the surgeon refuses to admit the total capitulation it really is.

And the medical world looks on in the same manner as in watching the weird work of aircraft raids with intelligent bombs during the Balkan War. Limb transplantation is more than a video game. For ethical reasons and for the sake of the medical profession, the license should be withdrawn from those who are unable to distinguish between a human being and a guinea pig.

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Conclusion

With all this in mind, best results in upper extremity amputation and prosthetics can serve as examples of successful interdisciplinary teamwork. Despite the limits set by nature, there still is so much one can improve in surgery and in prosthetics as well.

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REFERENCES

1. Baumgartner R, editor. Upper extremity amputation and prosthetics. Med Orth Tech 1992;1:5–51.
2. Baumgartner R, Botta P. Amputation und Prothesenversorgung der oberen Extremität. Stuttgart: Enke; 1997.
3. Irmay F, Merzouga B, Vettorel D. The Krukenberg procedure: a surgical option for the treatment of double hand amputees in Sierra Leone. Lancet 2000; 356(1):1072–5.
4. Marquardt E, Franz E. Autofahren ohne Arme, Arzt und Auto 1982;58:26–8.
5. Pillet J. The aesthetic hand prosthesis. Orthop Clin North Am 1981;12:961–9.
6. Mounib M, Kondoch B. Gerechtigkeit für Sierra Leone. Neue Zürcher Zeitung 2001;48:9.
7. Garst RJ. The Krukenberg hand. J Bone Joint Surg (Br) 1991;73-B:385–8.
8. Brückner L. Sauerbruch-Lebsche-Vanghetti cineplasty: the surgical procedure. Orthop Traumatol 1992; 1(2):90–9.
9. Brückner L. The Sauerbruch cineplasty and its positive effect on phantom limb pain. Med Orth Tech 2001; 121:3–10.
10. Atkins DJ, Meier RH. Comprehensive manual of the upper-limb amputee. New York: Springer-Verlag, Inc.; 1989.
11. Weir RF. Tunnel cineplasty as a control input for externally-powered prosthetic components. Med Orth Tech 2001;121:9–12.
12. Böni Th, Spormann C, Wetz HH, Baumgartner R. Skeletal anchorage of prostheses in amputees—a review of obtained results. Med Orth Tech 1999; 119:151–5.
13. Zimmermann KW. One leg in the grave. Maarssen Holland: Elsevier/Bunge; 1998.