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Comments on Orthopaedic research in amputation surgery, prosthetics and orthotics by N. C. McCollough

The above paper was published in Vol 5, No. 1 of the Journal. Comments were invited from a number of distinguished practitioners and have been received as follows:

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I wish to comment on those facets of the presentation which I find provocative.

Direct skeletal attachment

So much could be done from a direct reconstruction using biologically acceptable processes that direct attachment across the skin barrier can wait. For example, something could be done again with bone bridging. We know a good deal more now than we did when Inman and Loon carried out their trials of that technique. Also, something should be done with respect to exploiting the body's capacity to develop callus. I would like to see displacements of selected segments from one site to another so that what is of value (say for weight bearing) could be salvaged from one level to be used at another. Furthermore, should implantation be of value, I would like to see such implants *within* the body (similar to Swanson plugs) which would improve interfacing the prosthesis with the residuum for end bearing. I visualize a surface of similar breadth to the femoral condyles (trimmed?) which would provide the area necessary, and skin conditioned by callusing to transmit the required forces.

Lower limb prosthetics

The emphasis of design and development should be directed toward establishing ever improving standardized prefabricated sockets using quite different techniques for their construction than we now use. Adjustability would be included and, as indicated by McCollough, responsiveness to residuum changes. Electrically driven alignment systems permitting alignment adjustments to be made as the person walks would be worthwhile, as was demonstrated in Winnipeg during the 1960's.

Refinement of the endoskeletal prostheses as proposed is correct. The systems presently used are all doing the same thing in different ways. Greater standardization of the bolts and nuts should be introduced so that parts become interchangeable betwen systems now classed as different. Joints could be moulded directly from plastic so that hingeing occured as a result of thinning the plastic in strategic locations; in this way any pattern of hingeing could be programmed in. The use of such internal hinges would suit the design of children's prostheses because of the size problem. This would lead to a similar approach to the hingeing of orthoses. I would like to see cosmetic restorations constructed out of elemental sections which could be interlinked; such cosmetic systems could be made adjustable and mobile.

A strong effort needs to be mounted to sense shape and replicate it by automatic means. The craftsmen will then have a most powerful tool with which to carry out their fittings so that as they learn, what they learn remains secure in computer memory. In this way the experience of each artisan can become common to all rather than a private preserve which perishes with him.

Lower limb orthotics

The emphasis should be placed on investigations and applications which link scant biological functions to reinforcing technological

inputs as illustrated by functional electrical stimulation and comparable systems. At the same time there must be mechanical systems which will supplement or substitute for the functions we may reasonably expect to be derived eventually from procedures such as FES. The mechanical systems should be modular and that includes modularization of the support surfaces. There are numerous straight line regions on the body which should be exploited to make modularization of orthoses easier. Also, there should be a trend toward plastic tubular structures which in themselves are fragile until they are interlinked in ways that stiffen them in required directions so that a *system* develops instead of an *orthosis*. Thus, given spinal stabilization as the problem, tubular structures would be shaped around or along body parts to conform, and then be stiffened by other sections interlinked in truss form.

When McCollough speaks of research into materials it is likely he means the application of new materials. Such materials are used for what they will do. Thus, the graphite reinforced plastics are used where stiffness is required. Polyethylene tubing is used where the orthoses must form in against the body. Vacuum formed structures are used where the shapes are well defined. As suggested, there should be more aggressive attempts to apply modern computer technology such as microprocessors to problems of control. Repetitive patterns can be fed in by the patient and used until a changed pattern is required. With respect to fracture bracing, the need is for a modular approach to surfacing and containment which makes plaster obsolete. The system would be instantly appliable, continuously adjustable and impervious to water etc.

The development of emergency orthoses should be given a fairly high priority for the reason that such limited use systems will provide insights which will never be gained by refinement of existing systems. Such systems, because they can be designed without reference to cosmesis and will need to be adjustable to make them universally applicable, will lead us to the new generation of orthoses so badly needed. Because the spine is so accessible, can be treated as immobile and has such broad areas for force transmission, it is an attractive subject for which to develop "immediate application" orthoses.

One final point—many of the applications which are discussed with knowledge and confidence are areas in which I am ignorant. There was a time in our fair world when we (CPRD) knew what was going on everywhere and each contributed his knowledge to others. There is a dire need for some mechanism which will ensure an exchange of information. I suggest that ISPO be paid at advertising rates to publish in this journal brief progress reports from the various projects where innovations are being developed.

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It is difficult to add new ideas or to be critical concerning the projects proposed by McCollough in the April, 1981 issue of Prosthetics and Orthotics International, and therefore, for the most part, this presentation is restricted to amplification of the ideas set forth in that article.

Amputation surgery

1. The work currently being supported by Johnson and Johnson[1] in the use of coral calcium carbonate microstructures converted to hydroxyapatite (Holmes, 1979) as a substitute for bone in grafting procedures should be followed closely with the idea that stump length and function could be enhanced. If this technique is successful, the Marquardt

[1]New Brunswick, New Jersey, U.S.A.

osteochondral transplant procedure (Marquardt & Neff, 1974) probably could be simplified, and new reconstruction techniques might be possible especially when electrical current is used to stimulate bone growth.

2. While scientific evaluation of the merits of myoplasty and myodesis (Dederich, 1963) relative to more conventional procedures is probably not practical, a survey of patients who had such surgical procedures from, say, 1960–1970 would probably produce useful information. The bulk of the patients to be studied are probably in Germany, but patients from other countries should be included.

Lower limb prosthetics

1. The development of lightweight artificial legs should be accompanied by studies to determine the effects of weight reduction and weight distribution of the prosthesis on amputee performance. For the first time, we have available techniques and materials that permit practical fabrication of safe, functional artificial legs that are extremely light (Wilson & Stills, 1976), thus opening the way for experiments that will provide the information needed to determine optimum weight and weight distribution.

2. A simple method of measuring the change in energy requirements during level walking as weight and weight distribution are changed would be extremely helpful in this study, in alignment studies, and in lower-limb orthotics research.

3. The alignment studies proposed should include an extension of the work of Hobson (1972) where an adjustable leg that permits the patient to control alignment was used. I have been impressed that some patients would always select the same alignment, which was not always the case with the prosthetists, and the prosthetists and patients did not always agree on the optimum alignment. A variation of this study would be the development of a method for the determination of the optimum gait pattern for each amputee.

4. It certainly seems that the physical properties of polypropylene and other olefins (Stills & Wilson, 1980) lend themselves for the development of sockets that can be adjusted to accommodate changes in stump volume, while at the same time providing a socket that has a more flexible and thus more comfortable brim (Bennett, 1974).

Upper limb prosthetics

1. In a single case at the University of Virginia some years ago the use of a hydraulic system for power transmission (Goller & Lewis), in place of a Bowden cable appeared to be both satisfactory and quite superior to current practice. The obvious advantages are greater efficiency and the same efficiency at every position of arm and forearm. The patient involved in the study was a welder. This study should be reactivated.

Orthotics

1. Work in functional electrical stimulation (CPRD, 1972) should be given high priority. Extensive studies are needed to determine if functional regain in stroke cases is accelerated by use of FES as early as possible after onset. Many therapists feel that this is true but no evidence has been accumulated to prove it scientifically.

FES used in conjunction with all types of external orthoses should be studied. It might well be that some useful synergistic actions can be found.

General

1. Although considerable progress has been made in studies concerning the effects of mechanical stress on human tissues, especially the soft tissues, much more is needed for the advancement of rehabilitation and orthopaedic surgery.

Exact knowledge of the mechanism that results in pressure sores is yet to be determined.

The optimum pressure and pressure distribution between amputation stump and prosthesis are not known. Such knowledge, obviously, would permit better service. The same is true in the case of orthoses.

Almost nothing is known about the effects of shear stresses developed between prosthesis and patient, between patient and bed, and between patient and orthosis, including the shoe. Measurement techniques present the biggest problem here.

2. The use of the dilatency principle in casting stumps and other body parts has been studied

from time to time since 1945, usually with the idea of taking some of the art out of the process of modifying the positive model (Hägglund, 1975; Wijkmans & de Soeto, 1978). Another advantage of course is elimination of the mess and expense resulting in use of plaster-of-Paris bandages. With the advent of sheet plastics for fabrication of sockets and orthoses, a practical method of using dilatency would eliminate the need for wet processes altogether.

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My compliments to Dr. McCullough for the fine analysis and summarization in his article. His keen knowledge and interest in current prosthetics and orthotics are the prerequisites of a successful surgeon, researcher and lecturer, and give authority to his recommendations and priorities.

Dr. McCollough has covered the subjects well, and there is little, if anything, one can disagree with. My personal opinions as practicing prosthetist therefore focus on my specialty, clinical observations and priorities from the prosthetist's viewpoint.

Amputation surgery

In spite of all the surgical improvements in amputation surgery, research should continue into refinements of techniques, specifically muscle stabilization techniques such as tension myodesis and myoplasty.

The value of the Ertl osteoplastic procedure and the Swanson method of silastic distal bone caps to achieve improved end bearing characteristics in below knee residual limbs should be further investigated and its desirability re-evaluated.

For vascular surgeons, a precise criteria for revascularization of the dysvascular ischaemic limb should be popularized. Bypasses and grafting techniques should be avoided if the chances for ultimate success and the saving of the limb are slim, since many of the failed vascular reconstruction attempts result in a pain syndrome that severely compromises residual

limb comfort and diminishes prosthetic tolerance following below knee amputations. Additionally, the amputation level might be lowered if marginal revascularization procedures are avoided completely and a primary amputation is elected instead.

Postsurgical patient management

Immediate postsurgical prosthetic fitting has been standardized to a large extent and proves to be the patient management of choice. However, certain technical improvements are still indicated in the areas of rigid dressing suspension in the above-knee. Residual limb management in the interval between rigid dressing, discontinuation, and definitive limb fit is an area that requires improvement. The indication for a preparatory prosthesis or immediate definitive prosthesis, including the value of ambulation activities of geriatrics in the immediate postsurgical period, are possible areas for further research.

Prosthetic socket interface, design and suspension

The quadrilateral total contact above-knee socket design has brought about much improvement over the open end oval or plug fit socket it displaced. However, the above-knee geriatric amputee requires further improvements in socket design modifications, and materials that are less rigid and restrictive while the patient is seated and while being flexible, are still sufficiently supportive during ambulation.

The above-knee suspension systems for the geriatric amputee and the obese patient require prosthetic research and development. Hip joints and pelvic belts are cumbersome, bulky, restrictive and uncomfortable to many patients. Silesian belts are at best only partially effective. A modified Silesian belt or elastic suspension system that can be worn with comfort and handled confidently by a geriatric is a major requirement.

Similarly, socket interface design and suspension for the young, vigorously active and sports oriented amputee must be considered. The Prosthetic Research Study (PRS) in Seattle has been very active in recent years investigating high performance prostheses for such activities as snow and water skiing, running, tennis, cycling, basketball, baseball, and mountain climbing. Research should centre on the most suitable socket interface, soft vs. hard or combinations of both; the form of effective socket suspension, auxiliary, suprapatellar, supracondylar, hip, waist or combinations thereof. Also the dynamic alignment principles for these high performance prostheses differ greatly from conventional prosthetic principles and should be further studied and developed.

Important research is also being carried out by PRS on voluntary limb musculature control and the training of patients in conjunction with self suspending below-knee sockets. These developments could have significant impact on altering and possibly eliminating conventional socket design and suspension systems and enhance the voluntary control of the prosthesis by the patient. Below-knee residual limbs that allow increased distal end weight bearing (Ertl osteoplasty and Swanson's silastic plug) require research into modified socket designs that accommodate these advantages and probably allow much looser proximal socket fitting techniques. These studies should be encouraged and continued.

Additionally, the use of rotators or other torque absorbing devices or materials should be included in these studies and investigated.

Prosthetic feet and ankle joints

There are numerous prosthetic ankle and foot designs currently commercially available. While some are alike, others are distinctly unique in design and function. A complete review and a uniformly controlled testing and evaluation of these devices might help to establish some useful guidelines when selecting a particular type for a given patient. For years the SACH foot has enjoyed wide popularity and use; it should not be the final word in prosthetic feet. New materials and technology should allow for improvements in current designs. For one, more flexibility would be a desireable feature. The SAFE foot developed by Campbell and Childs is such a development and encompasses many features not found in previous designs. Another design currently being evaluated is the energy storing type of SACH foot that provides stored energy at the push off phase and improved function by providing a dynamic spring performance in active individuals. The multi-axial Greissinger

foot, including the hydraulic design by Habermann and the new Mauch hydraulic foot place emphasis on increased function and are definite improvements in foot designs. This work should be encouraged and continued.

Casting techniques and measurements

Research into casting techniques to provide accurate residual limb replicas or positive moulds is required. Direct moulding of suitable plastics should also be continued. More accurate measuring techniques or systems should also be considered and investigated.

Hip disarticulation and hemipelvectomy prostheses

Engineering refinements and new sources of energy are needed specifically for the hip joint of hip disarticulation and hemipelvectomy prostheses. This applies for both endoskeletal and exoskeletal designs. A noteworthy development in this area is the Concept 80 Hip Flexion Bias System (HFB) by the Medical Centre Prosthetics Inc. which applies an energy storing system adapted for the Otto Bock endoskeletal system. Research and development in this area should continue.

Prosthetic components for children

There is still only a limited array of upper and lower extremity prosthetic components available for children. Simple scaling down of adult size components to child sizes is not always successful in view of the rugged demands placed upon the components by this particular group of patients. Knee-shin set-ups and swing phase control systems, including knee disarticulation systems are areas requiring attention. Softer, more flexible and waterproof foot designs that can be worn barefoot on the beach are also needed for children.

Upper extremity components for children show greater availability of suitable sizes, but these developments should be continued and further expanded.

Partial foot prostheses

There are numerous techniques and systems practiced in the fitting and fabrication of partial foot prostheses. While certain designs and fabrication techniques are used in some areas with great success, they are virtually unknown elsewhere. A collection of the various fitting and fabrication processes and publication of a manual on the subject would fill a void in the prosthetic education system and could even prove financially rewarding to the authors and publishers.

Education and dissemination of information

Education and dissemination of information are vital to our professions. New developments as well as basic procedures must be taught and understood in order to be practiced responsibly. The prosthetic schools in the USA and elsewhere fill this role effectively. Their continued existence must be assured for the benefit of the patients we serve.

For research, development and evaluation, we need a forum to organize and bring together the researchers, developers, evaluators, experts and educators to present the current state of the art and to discuss results and findings. This form of interchange of ideas avoids duplication of efforts and resources. The Committee of Prosthetic Research and Development filled this role effectively for many years in the USA before it was discontinued. A replacement is badly needed.

Professional publications and seminars are only partially effective due to the inherent time lag in comparison to specialized workshops that deal in depth with particular subjects and problem areas on a continuing basis.

If the successful developments of the past are an indication, I am positive the beforementioned problems can be resolved satisfactorily in the near future.