Clinical Prosthetics & Orthotics

Management of Contractures

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The Nature of Contractures

by Justin Alexander, Ph.D.

When orthotic devices are supplied to a patient, it is generally in the hope that function can be enhanced. If this expectation is to be realized, joint mobility or range of motion should be within normal limits. Unfortunately, there are many patients where a significant deficit in freedom of movement occurs. It is essential to realize that the causative factor for such limitation is varied, so that one may develop a reasonable treatment approach.

Impedence to free motion can result from injury or malfunction of the skin overlying a joint, muscles or tendons surrounding or crossing joints, the joint capsule, or the joint surfaces. In many instances joint disturbances can be avoided by timely intervention such as correct positioning; active, assistive or passive exercises; or stretching and joint mobilization. Unfortunately, even when meticulous care is provided, limitations of movement can occur. Once tightness has been allowed to develop, it becomes more difficult and painful to restore normal function. A variety of mechanical devices designed to minimize the danger of developing contractures, or to overcome them, have been described in the literature. Surgical intervention may be attempted in carefully selected instances as well.

A common sequela to prolonged inactivity is loss of flexibility, probably due to shortening of muscle fibers and connective tissue. In an otherwise healthy individual this does not cause a serious problem and one can expect that with resumption of normal activity, muscles will regain length and flexibility. If, however, a limb is immobilized because of injury or disease, tissue repair involves replacement of muscle fibers with scar tissue which consist of collagen. Early, persistent, and careful physical therapy usually produces satisfactory restoration of movement.

Delay in starting therapy or placing the responsibility for performing a prescribed regimen completely on the patient or family member, without assurance that the program is understood and that it will be performed, is prone to produce serious impedence to normal mobility. It is important to note that when a distal joint is immobilized, the more proximal joints are not utilized as much as under ordinary conditions and secondary joint limitation may develop. Some common examples are the concommitant tightness of hip flexors and knee flexors, or the limitation seen in the shoulder and elbow of the patient who has sustained a Colles fracture of the wrist.

Immobilizing a part in a resting position does not necessarily produce limitation of movement, provided there is physiological rest.[1,2] On the other hand, if a part is immobilized and there is active muscle contraction to prevent the muscle from being elongated or the joint moved, muscle tightness can be invariably expected. When a person expects that motion might be painful, such as during the acute phase of Rheumatoid Arthritis or during severe and prolonged periods of ischemia, a "protective spasm" can be anticipated and frequently results in "irreversible contracture." The term "irreversible" must be used tentatively, since, if given enough time, the contracture may be relieved through ordinary activity.[3] In most instances, therapy cannot be provided or justified for the long period required to ameliorate the situation. In several instances, we have observed changes occuring over two years or longer following initial insult.

Extravasation of fluid into tissue surrounding the joint, such as may be observed following repeated trauma as a result of stretching which is performed too enthusiastically, or after episodes of bleeding in an individual with hemophilia, will invariably result in deposition of collagen and may continue to permit calcification of the capsule and end in heterotopic bone formation.

Heterotopic ossification presents a difficult problem to manage. While there have been some reports of spontaneous remission over time, others have reported recurrence after surgical excision.

Repeated insults to the integrity of the joint itself can lead to complete blockage of the joint, either as ankylosis of the capsule or due to fusion of the joint surfaces. Depending on which joint is involved, total or partial joint replacements have been very successful in restoring function and almost completely eliminating pain.

The management of the patient with contractures is complicated and if it is to be successful, close collaboration between physician, therapist, orthotist, and the patient and family is

imperative. In the presence of contracture, the application of an orthotic device can be wrought with danger. If too much tension is applied in order to gain motion when the patient is walking, protective spasms may counteract any stretching effect. It is also possible that excessive pressure can result in a fracture, especially if the patient has ben inactive for some time and if osteoporosis is present. The chances of successfully reducing joint limitations are increased when physical therapy and orthotic devices are combined in a comprehensive treatment program.

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Orthotic Correction of Blount's Disease

by Terry J. Supan, C.P.O.
John M. Mazur, M.D.

INTRODUCTION

Infantile tibia vara is the result of abnormal growth in the proximal tibial epiphyseal late of the tibial plate. Blount[1] first identified the condition as osteochondrosis deformans tibialis in 1937. Clinically, tibia vara presents itself as a severe bowing of the proximal tibia, without the associated bowing of the tibial shaft or the femur, which is evident in physiological bowleg. On radiological examination of the child with tibia vara, a beaking of the medial aspect of the tibia metaphysis is noted. In 1964, Langenskiold and Riska[2] developed a grading system for chronologically staging the development of the Blount's disease. Mitchell, et al.[3] advocated the use of the epiphyseal metaphyseal angle (E-M angle) as a simple quantitative measurement for Blount's disease in 1980. This method is useful to determine the severity of the disease and monitor treatment.

Historically, the use of orthotic management in the correction of Blount's disease has not proven to be as successful as hoped. The lack of correction and increased laxity of the joint capsule of the knee have been the main reasons for not continuing with orthotic management. To this point, the treatment of choice for individuals with Stage IV or an E-M angle of greater than 30° has mandated that the child undergo one of several types of tibial osteotomies. Because of the high incidence of complications[4] and the recurrence of the condition, the authors felt that a new orthotic approach should be investigated. The result of that investigation has been the development of a knee-ankle-foot orthosis. This orthosis has successfully been used in seven cases of Blount's disease.

ORTHOTIC DESIGN

Previous orthoses used in the treatment of Blount's disease have been either a KAFO with a medial side bar only, or a KAFO with bilateral side bars. The medial side bar KAFO incorporated a varus corrective knee pad. The bilateral side bar orthosis is essentially a passive device to maintain the existing condition and to prevent it from getting worse. Neither system has proven to be completely successful in the treatment of Blount's disease.

The design criteria established for the development of the knee-ankle-foot orthosis con-

imperative. In the presence of contracture, the application of an orthotic device can be wrought with danger. If too much tension is applied in order to gain motion when the patient is walking, protective spasms may counteract any stretching effect. It is also possible that excessive pressure can result in a fracture, especially if the patient has ben inactive for some time and if osteoporosis is present. The chances of successfully reducing joint limitations are increased when physical therapy and orthotic devices are combined in a comprehensive treatment program.

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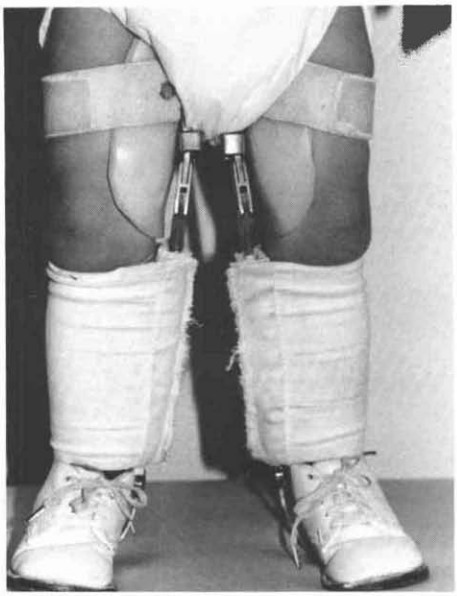


Figure 1. Bilateral KAFO's for Blounts with stainless steel medial side bar, thermoplastic femural section, and elastic tibial strap. Femural section protects the knee joint while the elastic applies maximum force to the apex of the tibial curve.

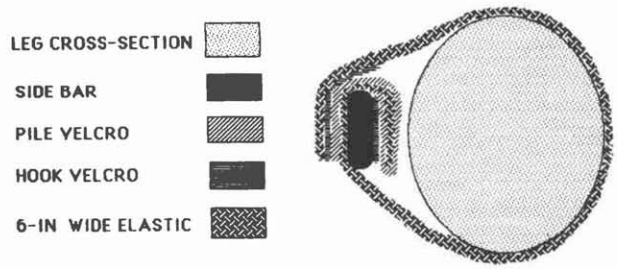


Figure 2. Cross section of leg and orthosis at mid-tibial level. The relationship of the sidebar, elastic, velcro, and limb are shown.

sists of the following:

- The design must correct the varus deformity of the tibia.
- The medial joint capsule should not be distributed by the orthosis.
- Forces should be applied directly to the tibia and not the full length of the limb.

Because the patient is a growing child, it must be adjustable for growth as well as easily cleaned by the parents. The knee-ankle-foot orthosis which the authors have developed has met all of these criteria.

Stress to the medial joint capsule was prevented by using an inversion of the supracondylar suspension technique used for below knee prostheses.[5] By having a medial thigh section extend beyond the joint space to the area of the medial tibial condyle, we were able to reduce the possibilities of applying stress to the joint space itself (Figure 1).

A dynamic system was used to apply corrective forces to the tibia. The use of an elastic material to provide dynamic forces has been well documented.[6] A six-inch wide elastic gusset material with velcro closures provided an adjustable and continuously applied force to the tibia (Figure 2). The maximum force applied to the limb with the elastic material is at the apex of the curve (Figure 1). This allows the maximum amount of correction with minimum amount of force. The velcro allows easy removal for laundering. All orthoses are provided with two sets of elastic straps.

The orthosis needed to be strong and adjustable because these children are growing and extremely active. The side bars are made of stainless steel which overlap for growth adjustment only between the knee and ankle (Figure 1). The knee-ankle-foot orthosis was not made adjustable proximal to this area in order to maintain the tibial extension of the thigh piece in its proper relationship to the tibial condyle. The patient's foot is maintained in a high top shoe which is attached to the medial side bar by means of a free ankle stirrup.

PRESCRIPTION CRITERIA

The E-M angle is used to determine whether the patient meets the criteria for orthotic management of the Blount's disease. The E-M angle is measured on an anterior/posterior x-ray of the knee. To construct this angle, a line is first drawn through two points on the base of the proximal tibial epiphysis, selecting the first point at the base of the normal lateral side of the epiphysis and the second medial point as far away from the lateral side as possible, but at the base of the normal non-depressed epiphysis. Next, determine the midpoint at the base of the epiphyseal center, then draw a second or metaphyseal line from the medial tip of the metaphyseal peak to the midpoint of the epiphyseal center (Figure 3). If this E-M angle is equal to or greater than 20°, then orthotic intervention is recommended. Mitchell et al. determined that the mean E-M angle for normal children was 3°-11°. Orthotic management is maintained for a minimum of nine months and at such time as the E-M angle is less

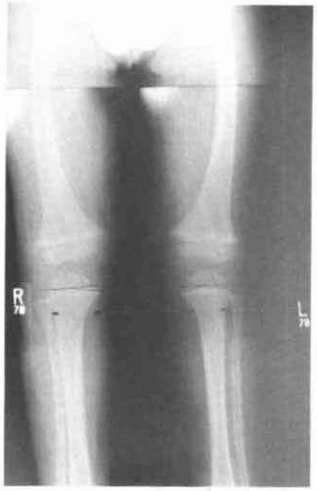
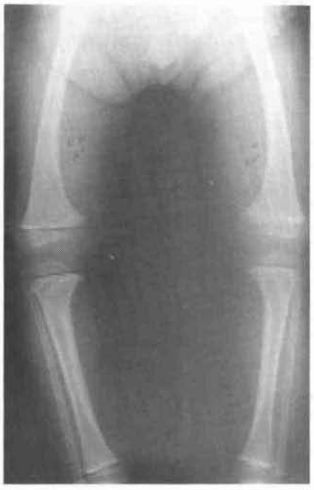


Figure 3 (left). Method of measuring the E-M angle.

Figure 4 (right). Clincal appearance of B.D. at age 3 with bilateral Blounts Disease.



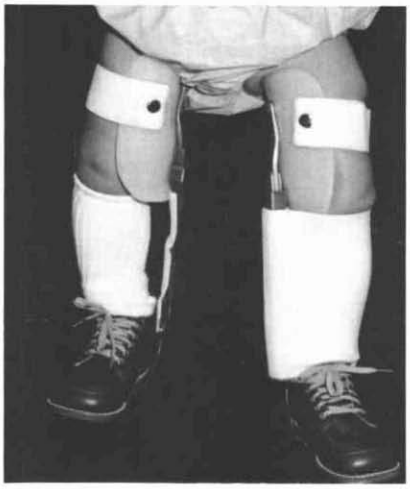
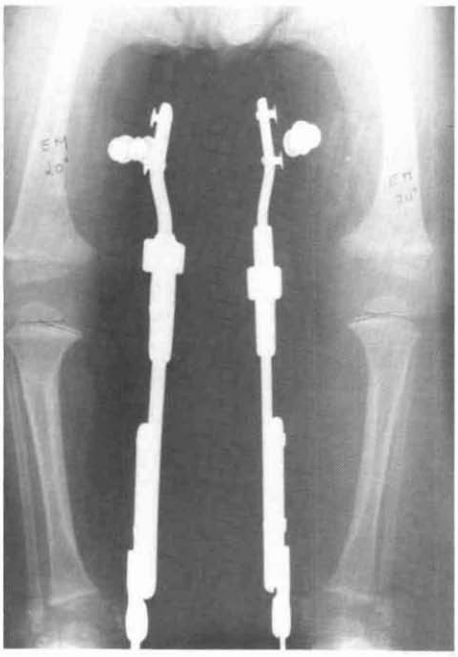


Figure 5 (left). Standing A/P radiograms show E-M angles of 20° bilaterally.

Figure 6A (right) and 6B (below). B.D. fitted with bilateral KAFO's. X-rays show no change at time of fitting.



than 15°. If the child is over eight years of age, orthotic correction will not be achieved. Based on our experience, orthotic management in stages I through III tibia vara can be effectively corrected with orthotic management. Aggressive treatment is necessary to achieve these results. Stages IV and V Blount's Disease and children over eight years of age need surgical treatment.

CASE STUDY

A white male, age 3, was presented at the orthotic clinic by his parents because of bowing of his right lower extremity (Figure 4). Clinical examination showed bilateral tibia vara. Bilateral standing AP radiograms were obtained. The E-M angle determined on these radiograms was 20° bilaterally (Figure 5). The child was fitted with the bilateral KAFO's (Figure 6A) and a new set of standing AP radiograms was obtained which showed no difference in the E-M angle at that time (Figure 6B).

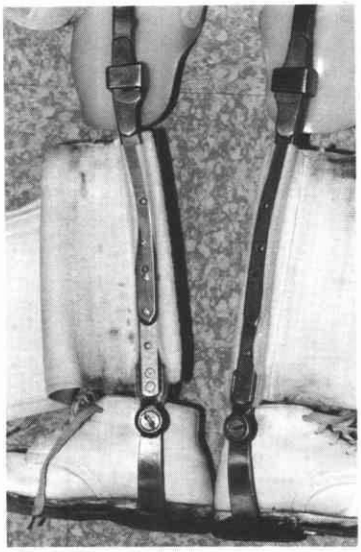


Figure 7. Sidebars were lengthened twice during the treatment period. One shoe transfer was also completed.

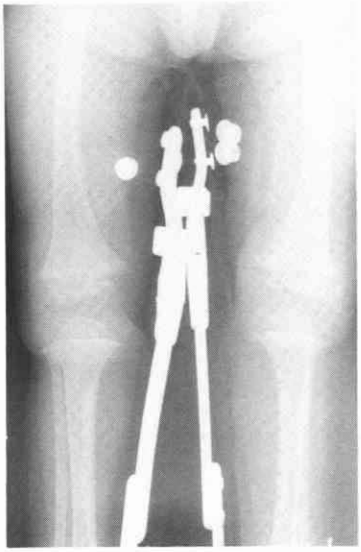


Figure 8. Radiogram taken after 9 months of treatment show an E/M angle of less than 15° as well as less bowing of the tibial shaft.

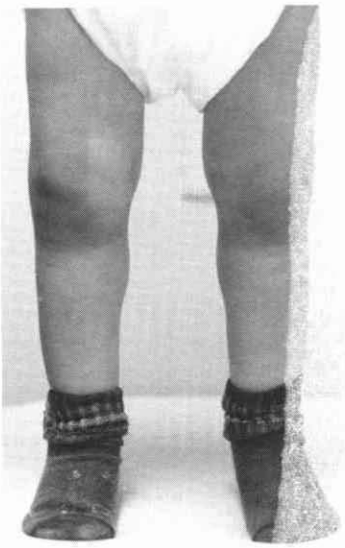


Figure 9. Orthotic treatment discontinued after 12 months. Clinical examination shows normal lower limbs.

For the next six months, B.D. wore his bilateral KAFO's 23 hours a day with the knee joints in the locked position during weight bearing. After one week's wearing time, the patient no longer objected to wearing the devices and adapted his lifestyle accordingly. No restrictions were placed on the child concerning his daily activities.

At his six-month checkup, new radiograms, both in and out of the KAFO's, were obtained. The E-M angle at that time was determined to be 15° bilaterally. Clinically, the child appears to have less bowing of his tibia as well. It was determined at that time that the side bars needed to be lengthened, which was done. It was decided that the parents could then allow the child to use the orthoses in the unlocked position during the daytime, but to return to the locked position at night. Because of growth of the child's feet, a shoe change was necessary.

At nine months, the patient was again presented to the clinic. Once again the orthoses were lengthened (Figure 7). New standing AP radiograms were also obtained, showing no significant alterations from the previous exam at six months (Figure 8). Day use of the KAFO was discontinued.

The patient returned for a twelve-month evaluation. No significant changes had occurred clinically in the patient's extremities (Figure 9), thus use of the orthoses was discontinued.

SUMMARY

This successful use of orthotic management in the early stages of Blount's disease has been proven at Southern Illinois University School of Medicine. An orthosis was designed to specifically meet the established criteria of correcting the tibial deformity, reducing the stress on the medial joint capsule, and allowing adjustability for growth. The device has been used in seven cases of tibia vara with excellent results in all cases. The E-M angle of the affected tibias have been reduced to less than 15°. Aggressive treatment in the early stages of Blount's disease will reduce the necessity of tibial osteotomies with their significant level of complications.

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Passive Mobilization: An Orthotist's Overview

by Dwain R. Faso, C.O.
Mel Stills, C.O.

INTRODUCTION

The application of passive motion in orthopedics has brought a new dimension to an old concept for the treatment of musculoskeletal problems. It is now recognized that the adverse effects of immobilization such as joint stiffness, poor articular cartilage nourishment, and collagen loss can be reversed by prolonged passive mobilization. R.B. Salter demonstrated significant results with his experimental work in the healing of osteochondral defects in rabbits subjected to continuous passive motion. R.D. Coutts followed with clinical experiences of improved range of motion after total knee replacements. The indications for passive motion have since broadened to include knee ligament reconstructions, injuries about joint, fractures, dislocations, joint sepsis, and many others.

The orthotist is often consulted for evaluation of passive motion devices, their set-up, adaptation, and implementation with fracture orthotics, external fixation, and traction. This article will provide an overview of passive mobilization as supplement to the practitioner's data base and present a variety of clinical situations encountered in the Dallas area at a large trauma and reconstruction center.

BACKGROUND

For centuries, the clinician has vacillated between the uses and benefits of rest versus motion in the management of various disorders and injuries involving body joints. Rest or motion have been the most prescribed forms of non-operative treatment, yet the controversy of indication, duration, and value of each is far from being resolved.

In the teaching of Hippocrates, the injured body was to be at 'rest and lie up.' His use of splints in musculoskeletal injuries assured rest. With the impregnation of bandages with plaster of Paris in 1852 by Flemish surgeon Antonius Mathijsen, immobilization took on a new form. The use of plaster casts in treating trauma and injury unquestionably assured the concept of immobilization by orthopedic surgeons for the next 130 years with little examination of the potential damage to articular tissue. Additional support of the rest concept was led by the British surgeon Hugh Owen Thomas. His doctrine of rest was to be complete, prolonged, uninterrupted, and enforced. This was accomplished through the use of splints of his own design, many of which are still in use today with minor modifications. Thomas' immobilization tech-

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niques routinely included uninjured joints above and below the fracture site.

The mobilization concept found its roots in the Aristotelian teaching that movement is life. In the late 1900's, a school of mobilization took on a significant form through its advocate, Dr. Lucas-Champonniere. This French surgeon supported the use of massage and motion as a means of preventing muscle atrophy and joint contracture during management of fractures and joint injuries. He believed that motion helped to relieve pain rather than to aggravate it. The use of balanced skeletal traction for fractures involving joint surfaces, initiated by Professor George Perkins, emphasized active motion in the realignment of fragments and prevention of stiffness.

In the 1950's, the 'movement is life' principle found a resurgence under the guidance of the Association for Osteosynthesis (AO). They coined the term "fracture disease" for the chronic edema, joint stiffness, muscle atrophy, and disuse osteoporosis found in the treatment of fractures with immobilization. The AO group's technique of open reduction, rigid internal fixation with compression, and no casting encouraged early mobilization and provided a significant aggressive treatment. Apley, Dehane, and more recently Mooney and Sarmiento advocated the closed functional treatment of fractures through the use of cast bracing. Although these two methods vary, both preserve joint motion and encourage early function.

CONTINUOUS PASSIVE MOTION

The human body has evolved and developed into an organism that needs to move in order to maintain optimum efficiency. When the body is immobilized, the overall physical fitness declines rapidly: the heart rate decreases, and cardiac output no longer rises sufficiently during even mild activity; the upright position is poorly tolerated; the nervous system response slows; calcium is released by the immobilized skeleton and is excreted in urine, reflecting the extent of bone loss; muscle atrophy occurs with the reduction of fiber size, thereby resulting in the decline of tensile strength and energy absorption capacity; and the immobile body loses three percent of its original strength per day in a linear fashion for the first seven days, after which little strength is lost.

The joints of the body are especially susceptible to immobilization. The articular cartilage layers depend on synovial fluid for nutrition. Motion makes for constant interchange of fluid between the layers of articular cartilage and synovial fluid. Joint motion causes alternating cartilage compression and distention. The absence of these pressure fluctuations causes a stagnation of intercellular fluid and a decrease in nutrition.

Surprisingly, the adverse effects of immobilization on the human body generated little interest for evaluation. In the 1960's, Salter began investtigation on the effects of immobilization versus mobilization on articular tissue in rabbits. His studies produced significant laboratory evidence that continuous passive motion offered startling benefits in the articular repair process in knee joint injuries compared to the routine care of immobilization. Salter's conclusions for his first 12 years of experimentation are:

- Continuous passive motion (CPM) is well tolerated and seems to be relatively painless.
- CPM has a significant stimulation effect on the healing of articular tissue, including cartilage, tendons, and ligaments.
- CPM prevents adhesions and joint stiffness.
- CPM does not interfere with the healing of incisions over the moving joint.
- The principle of rest for healing tissue is incorrect.

Evidence for clinical effectiveness of continuous passive motion on the process of healing is both subjective and objective. In various studies Dr. Richard Coutts demonstrated that there is a reduction in postoperative pain and an increase in post total knee joint range following the use of continuous passive motion for several weeks. The decrease in pain experienced may be caused from the rhythmic joint movement providing competitive interference to retard the pain-spasm reflex and alleviate pain at the source. The increase in range of joint motion reported may be due to the improved orientation and strength of collagen fibers formed, preventing adhesions which would limit range without disturbing or causing damage to adjacent uninvolved normal structures.

Clinically, Salter has indicated CPM use immediately postoperatively for the management of open reduction internal fixation (ORIF) of the ankle, knee, hip, and elbow with usage ranging from one to three weeks. Decreases in wound edema, joint effusions, pain medications, and an increase in patient comfort and shorter hospital stays are documented as compared to non-CPM patients. Schnebel and Evans found

that while active flexion is acquired earlier in CPM patients, there was no statistical difference in active flexion in late motion studies between CPM and non-CPM total knee arthroplasty patients.

DESIGN

Continuous passive motion machines can be categorized in three groups by design: mattress mounted, bed frame mounted, and single joint units. Clinical use of continuous passive motion has primarily been utilized for mobilization about the knee and hip joint due to the mechanical design of the majority of motion devices, i.e. the mattress mounted units. These machines are similar in that the patient lies supine with thigh and calf held in the unit, and the knee and hip are mobilized simultaneously. (In these units the patient is unable to move about in the bed or make significant posture changes.) Ankle movement may also be provided. Some mattress mounted machines and their suppliers are:

Autoflex, *Chattanooga Corp.*
CAPE System, *Zimmer*
CK-7 Passive Motion Knee Exerciser, *OEC*
Danni-Flex, *Danniger Medical Technology*
Kinetec Passive Leg Exerciser, *Richards*
Powerflex 3000, *Biodynamic Technologies of Florida*
Stryker Leg Exerciser, *Stryker*
Sutter CPM 2000, *Sutter Biomedical*

The bed frame mounted units attach to standard overhead Bulkin frames and provide the versatility for mobilizing multiple joints. These systems are:

CPM K-10, *Sutter Biomedical*
Passive Mobilizer, *3 D Orthopedic Inc.*

Single joint units address specific joints of the body only. These are:

Miami Ankle Motion Machine, *Zoya Orthopaedic*
Kinetec Elbow Exerciser, *Richards*
CPM-5000, *Sutter Biomedical*
CPM Mobilimbs L1-A, *Toronto Medical Corp.*

Functional features of all systems vary from: microswitching to torque sensing, mechanical range setting to computer programmed, 110 volt to battery operated, patient controlled cycles to programmed cycles, and one speed to variable speeds. Yet all systems have been developed more from subjective than objective data. The questions of how much force, optimum speeds, duration of cycle, direction of pull/push/lift to the joint, control of joint motion, or should the joint be loaded or unloaded need to be addressed in order to quantify CPM and avoid the potential dangers of this modality.

Dangers exist when these systems are utilized by those unfamiliar with mechanical systems and/or the expectant results they are trying to obtain. The level of knowledge required varies, i.e. the mattress mounted units are limited in application and therefore are relatively simple. The multiple joint systems would require more expertise because of the increased options of use, the mechanical advantages gained with the use of pulleys and springs, and the variations of movements occurring about the anatomic joints. These systems tend to be more cost effective since their various uses can be applied to a greater patient population.

TWO YEAR EXPERIENCE

In our experience at a major trauma hospital, the need for versatility, ease of use, and reliability were of utmost importance. We utilized five machine designs over a two year period: Sutter K-10, CPM Mobilimb L1-A, Richards Passive Leg Exerciser, 3D Passive Mobilizer, and a home grown unit. All systems functioned very reliably. The Mobilimb unit had a rechargeable battery powered system which, for our use, proved to be the least practical.

The mattress mounted units were limited to mobilizing knees and hips, especially in cases of joint replacement. The trays to these units were cumbersome to housekeeping. The staff would take the tray off the bed to change linens, causing frequent malalignments when setting it back on the bed, usually due to fear of reapplying and/or the lack of understanding how the system functioned. Patient comfort was a major concern. If the patient was not comfortable in the system due to the physical design of the system or improper positioning in the unit, the staff would turn off the machine, thereby reaping no benefits. The tray would not fit properly if the patient was above or below the average height of five foot ten inches. These systems did not provide a recorder to document how long the patient had the system on or how many cycles the limb experienced.

Lack of full extention and flexion became another concern in our use of any of the units utilizing the tray that the leg simply laid in. Although the tray would indicate full extension,

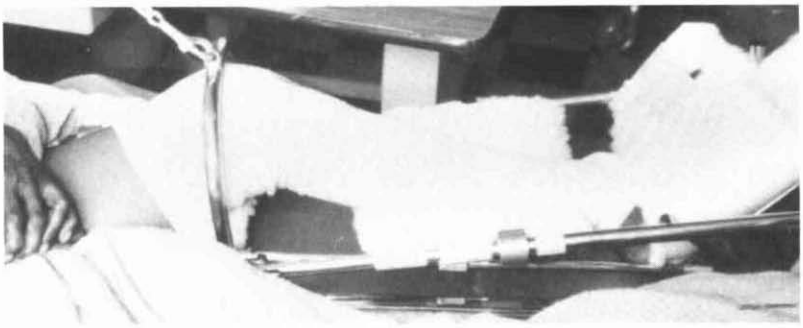


Figure 1.

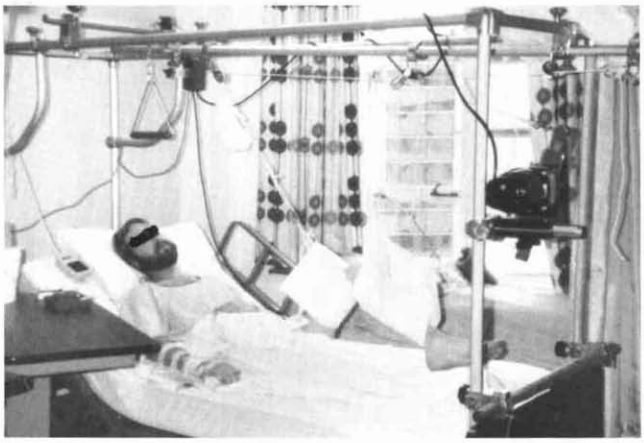
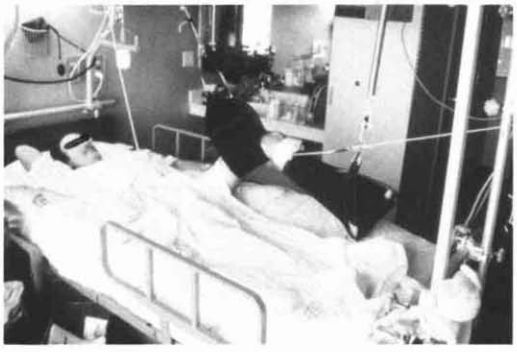


Figure 2. Home grown unit using Sutter K-10 motor and control system.

Figure 3 (below). Patient with right acetabular fracture with 30 lbs. of tibial traction in continuous passive motion (3 D Passive Mobilizer). Hip flexed 0-90° and kept abducted.



the leg would still be flexed, and usually abducted and externally rotated (Figure 1).

Because of these reasons and the need to be able to utilize traction, cast braces, and rehabilitative orthotics with passive motion, we began using a home grown version utilizing the Sutter K-10 without the mattress mounted tray. Through the use of dynamic suspension, we could achieve full extension with the assistance of gravity, mobilize a patient in traction, maintain abduction and adduction, and set-up bilateral limbs with only one machine. This variation enabled the patient to move about in bed and provided easier bed pan use and overall more comfort. It won favor with our ancillary staff because there was nothing in their way to be moved or replaced (Figure 2). In March 1984, we began using the Passive Mobilizer by 3 D Orthopedic Inc. This system had incorporated many of the features of our home grown unit with some significant improvements. The system provides a linear pull rather than the rotating arc of the Sutter K-10 so that flexion and extension limits are more easily controlled and eliminates the potential hazard of the rotating arm (Figure 3). Also, the unit includes a cycle counter to document how many cycles the patient has experienced. These two additional features were found to be very useful in our practice.

The use of passive mobilization should begin as soon as possible. The earlier the application, the better the results that can be anticipated. In the case of elective procedures, such as total joint replacements, the passive mobilization system should be set-up before surgery to familiarize the patient with the machine and its operation. At our center, the majority of the cases are trauma related and of a fracture variety. Patients are placed in passive motion postoperatively in the O.R., recovery room, or when transferred to the orthopedic floor. The unit is set to allow 30-40° of motion initially post-op with rapid increase of range of motion to tolerance.

In this two year experience, we have had 168 cases involving the use of continuous passive

motion. These are broken down into three major categories:

Articular Fractures

Knee	79
Hip	17
Elbow	4
Ankle	3

Joint Replacement

Knee	14
Hip (Cup)	8

Other Knee Problems

Sepsis	20
Lig. Repair	12
Edema Control	6

Continuous passive motion was also applied to mobilize the cervical spine (in halter traction post soft tissue trauma), the shoulder (post manipulation or rotator cuff repair), and the lumbar spine (post laminectomy or decompression). These were not listed because the applications are still under evaluation.

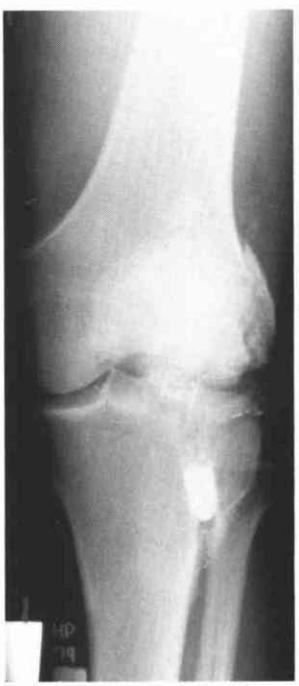
Our goal in utilizing the modality of continuous passive motion is full range of motion. Initially we target for 0-40° of motion the first day, cycling the limb approximately one complete cycle per minute. Increase in ROM is aggressively addressed daily to pain tolerance. Since time minimums in CPM have not yet been established, patients are kept in passive motion except during meals, physical therapy, or bathroom use.

The goal established for ROM of the knee and hip is 90+°. It was felt that if the joint could go through a passive 0-90+° range pain free, and prior to discharge 0-90+° active range, that normal knee and hip motion could be achieved on an out-patient basis with aggressive physical therapy. Many factors influenced the outcome. Patient compliance and willingness to participate in this treatment plan is a major factor. Competent application and training in the use of continuous passive motion is also critical to the outcome.

CASES

Case I

A twenty-nine year old male sustained a high caliber gunshot wound to the left knee (Figure 4), traversing the lateral femoral condyle through the joint space and through the lateral tibial plateau. Open reduction internal fixation (ORIF) and ligamentous repairs were made. Postoperatively, the patient was placed in a standard cast brace due to the inability to provide adequate medial-lateral stability of the knee surgically (Figure 5). The cast brace was attached to



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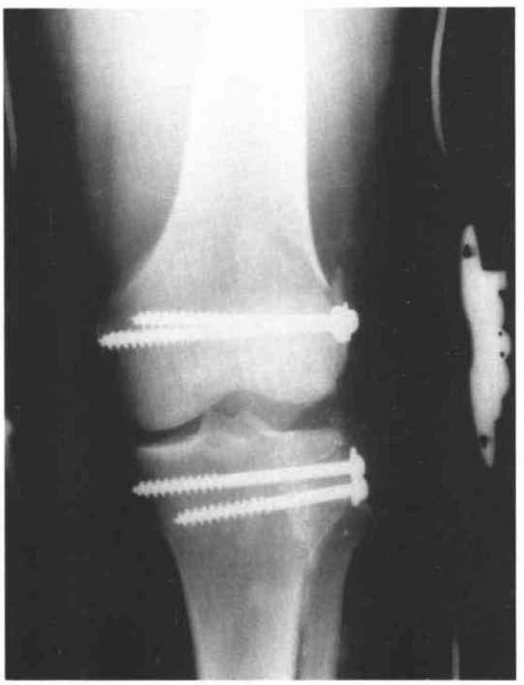
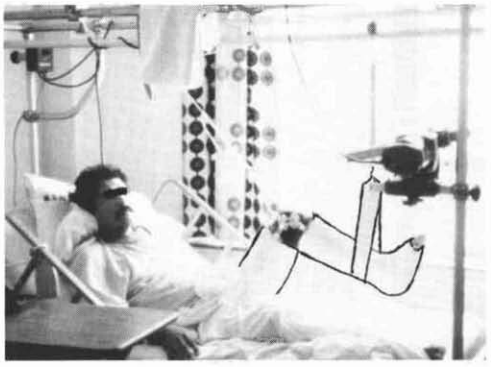


Figure 5.



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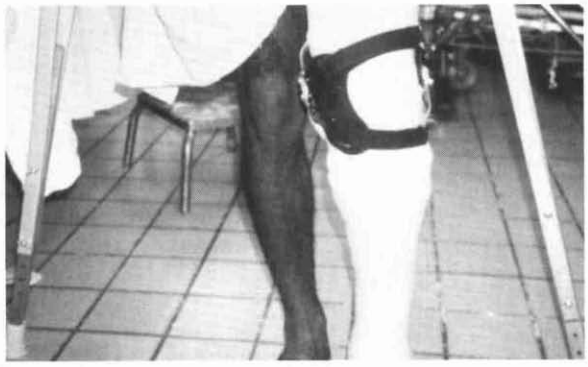

Figure 7.

a continuous passive motion dynamic suspension system to restore and maintain motion (Figure 6). At the time of the initial cast bracing, the patient had considerable soft tissue edema about the knee. The use of passive motion quickly reduced that swelling to the point where the cast brace provided little support. After one week, the cast brace was reapplied with the addition of a varus producing strap (Figure 7) and the patient began ambulation training and was discharged. (If atrophy or swelling should continue, the varus producing strap can be easily adjusted to maintain force on the knee and another cast change would not be required).

Case 2

A twenty-five year old female sustained a fracture dislocation of the left knee (Figure 8). The fracture and ligaments were internally fixed, and the patient was placed in a continuous passive motion dynamic suspension system utilizing a Mobilizing Brace (3 D) and a bootie (Figure 9). The patient achieved 0-90° of motion in two days and was maintained in passive motion for five days until she could achieve the same range of motion actively without excessive pain. The patient was then cast braced for increased medial-lateral stability, received gait training, and was discharged from the hospital.

Case 3

A nineteen year old male sustained a distal f racture with a split condylar fracture to the right leg (Figure 10) and a lateral condyle fracture on the contralateral side (Figure 11). Fractures were stabilized , but were not internally fixed at time of admission because of emergency vascular repairs being required. Three days post injury, the patient underwent ORIF of his fractures (Figures 12 and 13). The right leg was placed in a free knee Mobilizing Brace and the left leg was placed in the rehabilitative free knee orthosis. A continuous passive motion dynamic suspension system was placed on the lower right extremity (Figure 14). The lower left extremity had normal pain free motion following surgery. The patient was kept in passive motion for five days and achieved 0-100° of pain free motion. A cast brace

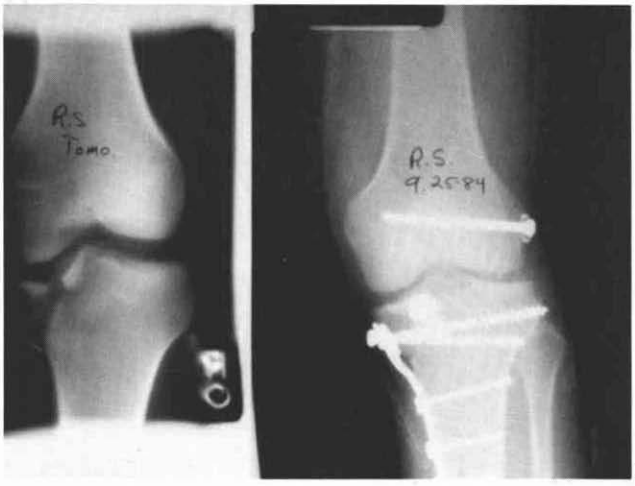

Figure 8.

Figure 9.

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1. Are the presence of contractures or related deformities a significant factor affecting your ability to meet your patients' needs?
   Yes _____
   No _____

2. Does the treatment of such conditions constitute a significant portion of your practice?
   Yes _____
   No _____

3. Which condition is the major factor affecting such patients?
   _____
   _____

4. What orthoses or other devices do you find most useful in treating such cases?
   _____
   _____

5. Other comments: _____
   _____
   _____
   _____
   _____

Send all completed questionnaires to: Charles H. Pritham, C.P.O., c/o Durr-Fillauer Medical , Inc., Orthopedic Division, 2710 Amnicola Highway, Chattanooga, Tennessee 37406.

Response to Questionnaire on Spina Bifida

There were seven responses to the questionnaire, all of which indicated that the respondents saw spina bifida patients in their practice. Four respondents stated that spina bifida patients represented less than 20 percent of their practice; two said that they represented 20 to 40 percent; and one 40 to 60 percent. Five practitioners saw patients in both settings. Four respondents employed the concept of a "wardrobe" of devices, three did not, and only one of the group had any experience with the concepts advanced by Mr. Glancy. Four of the practitioners had recent experience with the L.S.U. Reciprocating Gait Orthoses while three had not. One of the three who had not, however, had fit two orthoses (the criteria for recent experience was three orthoses fit in the past year). Three of the respondents were willing to participate in Mr. Supan's clinical evaluation.

ADDITIONAL COMMENTS: "Don't see new spina bifida patients, but older ones already in walking type orthoses. My use of the R.G.O. has been with paraplegics."

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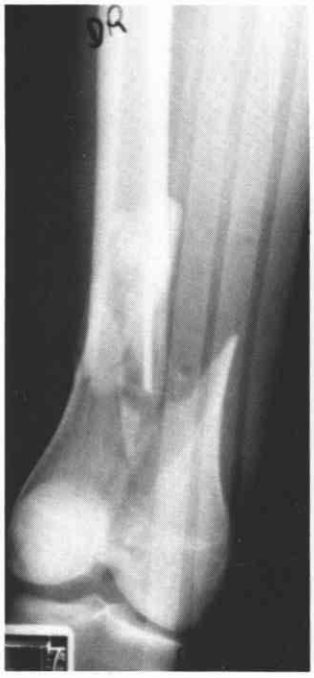
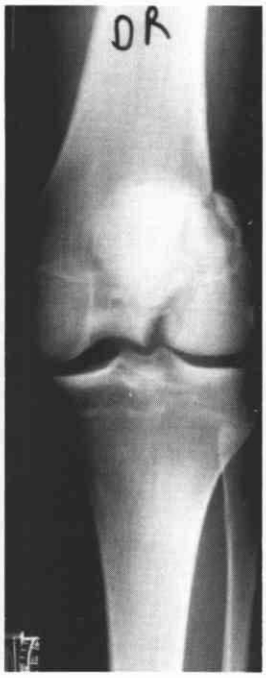


Figure 10.



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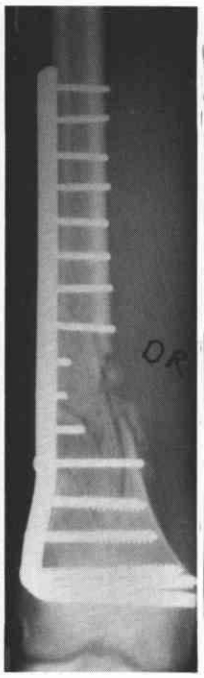
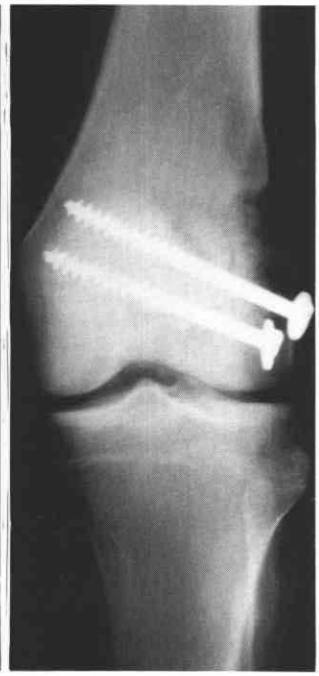


Figure 12.



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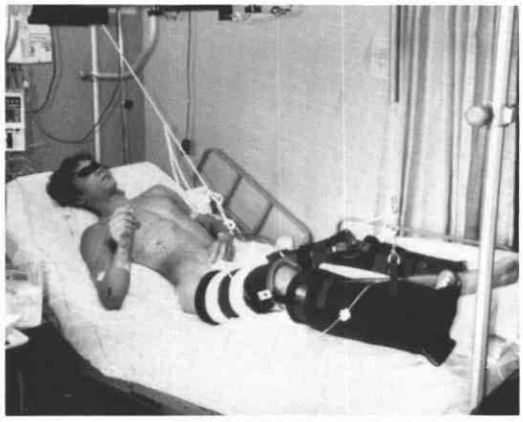


Figure 14.

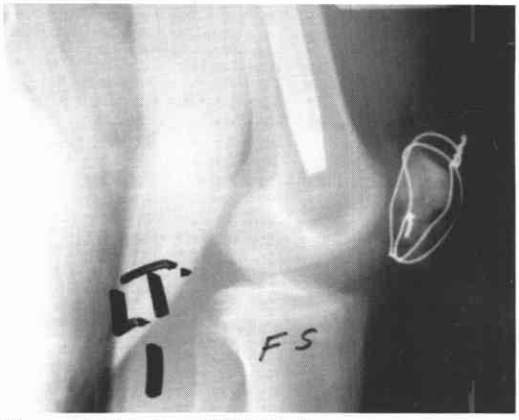
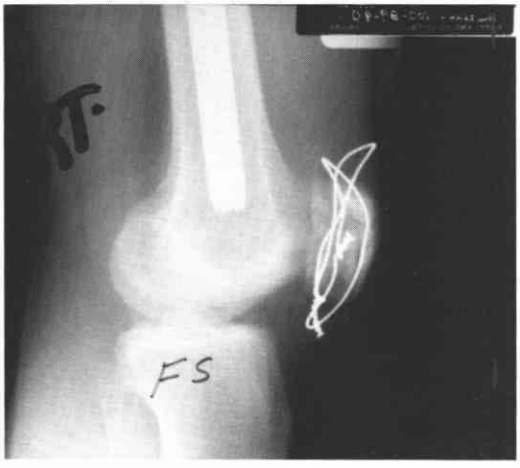


Figure 15 (above) and 16 (below).



was applied on the right extremity; the patient received gait training and was discharged.

Case 4

An eighteen year old male sustained bilateral femur fractures and bilateral patella fractures. The patient underwent bilateral closed intermedullary (IM) rodding of the femur and the patellas underwent bilateral ORIF (Figures 15 and 16). The patient was placed in a free knee Mobilizing Brace on the left leg and attached to a continuous passive motion dynamic suspension system immediately postoperatively. The right leg was maintained in a straight position and in a

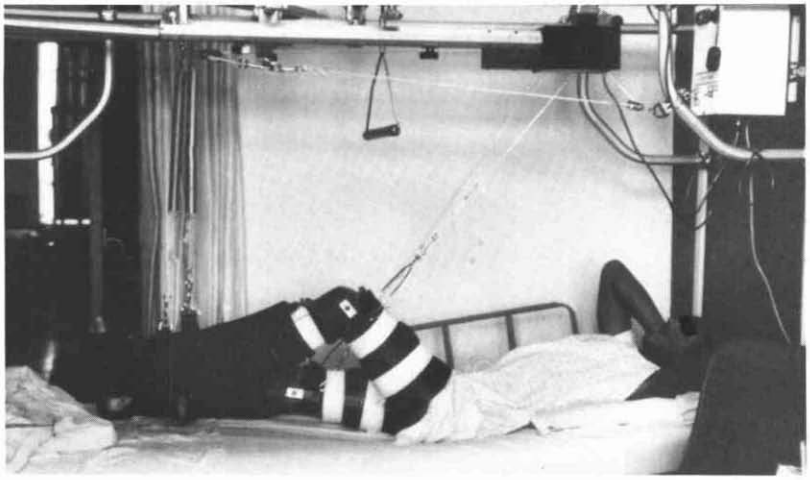


Figure 17.

Figure 18.

derotation boot to prevent the fractured femur from spinning on the IM rod. In two days, the left knee had 0-90° of pain free passive motion. Active motion on the right lower extremity was limited to 0-15° of motion. At that time, the patient's right leg was placed in a free knee Mobilizing Brace and bilateral passive motion begun (Figure 17). Right leg motion progressed to 0-90° passive motion in four days, while the left leg was maintained in the 0-90° range. (This passive motion device, providing bilateral application from one power source, can be adjusted for varying degrees of motion independent of each other by varying the tension on the attachment lines.) Ambulation training began utilizing the bilateral Mobilizing Braces with drop locks in position (Figure 18). The patient was fully ambulatory with this system, achieved full range of active motion in ten days, and was discharged. Passive motion was maintained for a longer period than normal due to the degree of articular damage to the patellas.

SUMMARY

Passive range of motion has proven itself as a useful treatment modality for increasing or maintaining range of motion of the hip, knee, ankle, shoulder, and elbow. Clinically, we have observed improved wound healing and reduction of edema. Septic joints that are or have been opened and drained appear to clean up sooner than joints treated with only incision and drainage (I & D) and daily whirlpool. Patients are comfortable with reduced requests for pain medications. Patients also seem happier and this may be due to the fact that something is being done to help them get better on a continuous basis. Therapy time can now be devoted to improving muscle control and independent activity levels rather than painful ROM exercises.

Of the 168 cases presented in this paper, all but two patients did or would have benefited from passive mobilization. The degree of success depended to a large extent on patient compliance. All patients who cooperated with this treatment modality improved their motion and reduced their hospitalization with two exceptions.

One patient had undergone total knee replacement and was placed in CPM in the recovery room. Approximately 20° of motion was achieved initially. All attempts to increase her motion failed in that the 3 D device would stall at a given point and reverse itself. The referring physician was contacted in order to report the difficulties. It was learned that the patient, some 40 years earlier, had undergone a spontaneous hip fusion probably due to infection. Conventional CPM can not be utilized for ROM of the knee if the hip is immobilized.

The second failure was with a young sickle cell disease patient also having severe sepsis of the knee. All attempts of passive mobilization were painful and limited to less than 30° of flexion. The patient underwent arthrodesis of the knee and was later discharged with granulating wounds.

Patients with fractures involving articular surfaces of the knee have done well with 0-90° of pain free active motion obtained in generally less than ten days. Depending on the degree of internal fixation or patient compliance, a cast brace was applied prior to discharge. As stated earlier, cast bracing and passive mobilization is a common treatment modality.

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Swedish Attempts in Using CAD/CAM Principles for Prosthetics and Orthotics[1]

by Kurt E.T. Oberg, M.D.

SWEDISH CAT/CAM HISTORY

In the mid-70s, James Foort and some of his colleagues began to investigate the use of CAD/CAM principles in prosthetics and orthotics. Others had also started to work in biostereometrics. Some colleagues of mine in Sweden and myself had initiated investigations in order to find modern technology which could be used in prosthetics and orthotics. Reports on this subject had already been published and showed promising possibilities of new techniques to be used.

Interest in CAD/CAM, however, was very low in Sweden at this time. Prosthetists and orthotists were very skeptical of the value of this kind of technology as applied to the improvement of prosthetic and orthotic technique. Therefore, further attempts in developing CAD/CAM technology for prosthetics and orthotics in Sweden were dropped. This skepticism was understandable because at that time the new technique could not possibly give us as good quality results as was already possible with the traditional techniques.

THE ISPO WORLD CONGRESS IN LONDON

During the 1983 ISPO World Congress in London, it became clear to Swedish prosthetists and orthotists who attended the congress that CAD/CAM techniques really had something to contribute to the field. The exhibition showed hardware such as measuring equipment and a

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Swedish Attempts in Using CAD/CAM Principles for Prosthetics and Orthotics[1]

by Kurt E.T. Oberg, M.D.

SWEDISH CAT/CAM HISTORY

In the mid-70s, James Foort and some of his colleagues began to investigate the use of CAD/CAM principles in prosthetics and orthotics. Others had also started to work in biostereometrics. Some colleagues of mine in Sweden and myself had initiated investigations in order to find modern technology which could be used in prosthetics and orthotics. Reports on this subject had already been published and showed promising possibilities of new techniques to be used.

Interest in CAD/CAM, however, was very low in Sweden at this time. Prosthetists and orthotists were very skeptical of the value of this kind of technology as applied to the improvement of prosthetic and orthotic technique. Therefore, further attempts in developing CAD/CAM technology for prosthetics and orthotics in Sweden were dropped. This skepticism was understandable because at that time the new technique could not possibly give us as good quality results as was already possible with the traditional techniques.

THE ISPO WORLD CONGRESS IN LONDON

During the 1983 ISPO World Congress in London, it became clear to Swedish prosthetists and orthotists who attended the congress that CAD/CAM techniques really had something to contribute to the field. The exhibition showed hardware such as measuring equipment and a

milling machine which gave an example of the automated socket fabrication technique. As a result of the London Congress, the interest in CAD/CAM for prosthetics and orthotics became quite high in Sweden.

SWEDISH ATTEMPTS

There is now a definite interest in Sweden and Scandinavia to implement CAD/CAM techniques into the prosthetic and orthotic field. The large company, LIC, which provides over 60 percent of the prosthetic and orthotic service in Sweden, and which also has started service in other countries, has a clear intent to adapt CAD/CAM techniques to their work. The first area to be involved will be the orthopaedic shoe service.

Another large prosthetic and orthotic service company, Een-Holmgren Orthopaedic Inc., is also following the work that is going on around the world in this field.

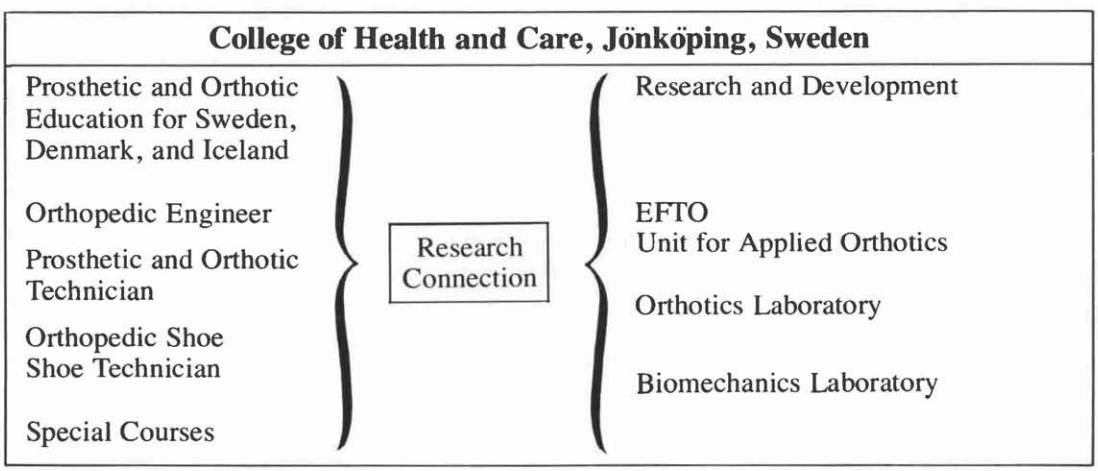
There are some counties in Sweden that run prosthetic and orthotic services themselves and they, too, are very interested in following and adapting CAD/CAM techniques. They have decided to seek co-operation with the work that is done by the College of Health and Care in Munksjöskolan, Jönköping, Sweden. My intention is now to present the research and development activities in Jönköping.

COMPETENCE AND EDUCATIONAL CONSIDERATIONS

The college runs the prosthetic and orthotic education programs for Sweden, Denmark, and Iceland. There are regular programs for orthopaedic engineers (2½ years), prosthetic and orthotic technicians (two years), and orthopaedic shoe technicians (two years). Various types and lengths of special courses are also offered at the school. The educational program is connected to research and development activities and divided into three laboratories. One laboratory is called the Unit for Applied Orthotics and is testing and evaluating orthotic appliances for the Swedish Handicapped Institute. Another laboratory is the Orthotics Laboratory, which has been involved in the development of prosthetic and orthotic devices for more than 14 years. The newest laboratory is the Biomechanics Laboratory, which I started two years ago.

There will be considerable consequences for a prosthetic and orthotic educational program when a technique like CAD/CAM is introduced into the orthotic and prosthetic field. The question for us is whether we should be passive and follow the development of techniques in different laboratories around the world, or whether we should be active in developing these techniques ourselves. The decision has been made that with regard to the resources and the competence we have in laboratories connected to the school, we should be active in development.

There already are some relevant resources available at the laboratories. At the Biomechanics Laboratory there is equipment such as computers, digitizers, image processing equipment, and lasers. There is also experience with digital measuring technique, computer programming and prosthetic and orthotic biomechanics. The Orthotic Laboratory has a machine shop and design office experienced in prosthetic and orthotic development and the development of various instruments.



Relevant Laboratory Resources for CAD/CAM	
Biomechanics Laboratory	**Orthotics Laboratory**
Equipment: —Computers —Digitizers —Image Processing Equipment —Lasers	Equipment: —Machine shop —Design office
Experience of: —Digital Measuring —Computer Programming —Prosthetic and Orthotic Biomechanics	Experience of: —P&O development —Instrument development

CAD/CAM PHILOSOPHY OF THE BIOMECHANICS LABORATORY

The philosophy of CAD/CAM in prosthetics and orthotics at the college and at the Biomechanics Laboratory can be expressed by the following criteria:

1. *The complete system should be available for each prosthetic and orthotic service shop.*

   The alternative is a centralized organization where central units are put in place for the fabrication of the prosthesis from data and measurements taken at the clinics and sent to the central workshop. With this kind of centralized organization, the whole advantage of the CAD/CAM technique cannot be fully utilized. Patients change for various reasons and it is important to use the CAD/CAM system when there are changes or when modifications are necessary. This can increase the effectiveness of the service quite a lot. It also enables the prosthetist and orthotist to have a better control of the whole process when making a device.

2. *The system should require moderate investment.*

   This criterion is only a consequence of the first criterion.

3. *Equipment of a very high specification (able to work to extremely close tolerances) should be avoided.*

   Very high specification is generally not needed, but if it does not increase costs, it usually does no harm. However, machines or computer programs which are too generalized (that works to too coarse tolerances) can increase the cost of the system tremendously and consequently should be avoided.

4. *Individual 3-D shape sensing should be the basis for control of the numerically controlled (NC) milling machine.*

   This is necessary in order to allow for individual variations that might occur, instead of working from more standard shapes, which is a simple but less effective way to work.

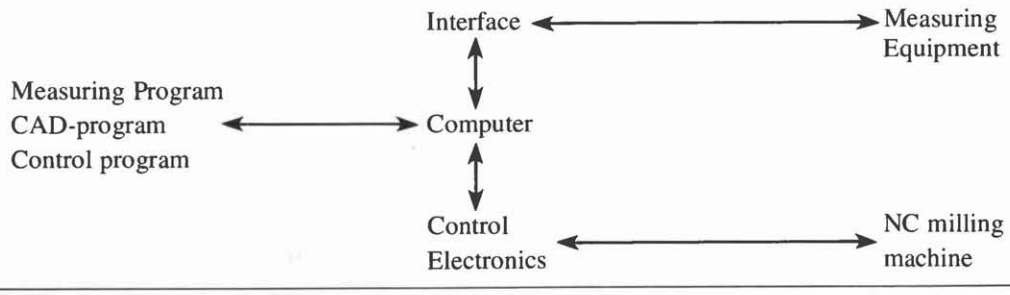
Criteria on CAD/CAM in Prosthetics and Orthotics

- A complete system should be available for each P&O service shop.
- The system should require a moderate investment.
- Too high specification of equipment should be avoided.
- Individual 3-D shape sensing should make the basis for the control of the NC milling machine.

OBJECTIVES OF THE CAPOD SYSTEM

There are potential possibilities for the use of CAD/CAM techniques in the whole prosthetic and orthotic field and the development that has been initiatied at the Biomechanics Laboratory in Jönköping therefore uses the name CAPOD as

The Principal Parts of the CAPOD System



an acronym of Computer Aided Prosthetic and Orthotic Design. The objective of this project is to develop a CAD/CAM system which fulfills the criteria mentioned above. The objectives of the CAPOD system are as follows:

- To develop a CAD/CAM-system for prosthetics and orthotics as one complete unit based on a micro computer.
- The cost of the system should remain within the range of US$30–40,000.
- To allow commercially available video image processing equipment to be adapted for 3-D shape sensing.
- To encourage the development of a specially designed NC milling machine, costing less than US$12,000.

TECHNICAL SPECIFICATIONS AND PROJECT STATUS

The principal parts of the CAPOD system will be a micro computer that controls both the measuring of the limb shape and also the NC milling machine by means of a measuring program, a CAD program, and a control program. Almost all these computer programs must be custom written. The fabrication cost of the whole system is estimated to be about $35,000.

The principal of the shape sensing scheme is generally the same as that developed at the West Park Hospital in Toronto. The plan is to take a video recording of a laser illuminated contour of the limb at increments of one one-hundredth of a turn. The videogram will then be transferred to the computer via the MicroSight image processing system. The software in the computer then takes care of data reduction and will define the surface of a limb as a set of digital coordinates. The custom made CAD program will then modify the shape as specified by the practitioner in a manner that corresponds to the plaster cast rectification process that he does today. At present, a Victor micro computer from Victor Technologies, Inc. is being used. This computer is equipped with an intel 8088 processor and has an internal memory of 256 Kb, which can be expanded to 896 Kb. It has 2×1, 2 Mb Floppy Disk, but a Hard Disk of 10,6 Mb is more likely to be used in the future. The monitor is 12″ and has a graphic resolution of 800×400 pixels.

Specification of the Measuring Equipment

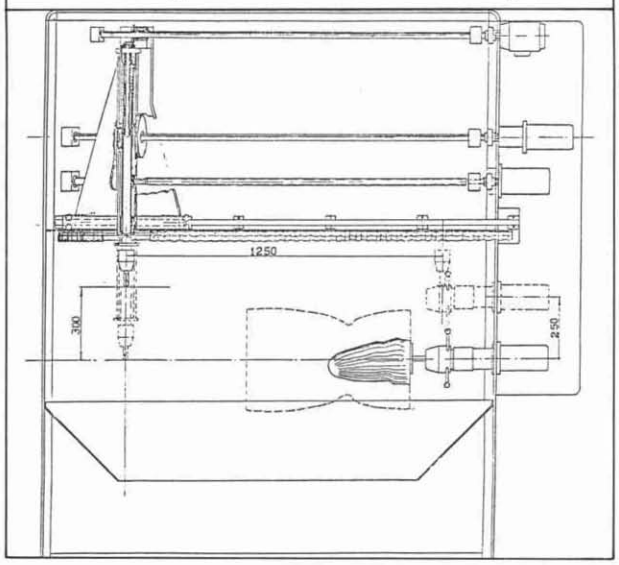
- Videorecording of a laser illuminated contour of the limb at increments of one one-hundredth of a turn.
- Transfer the videogram to the computer via MicroSight image processing system with 256×256 pixels per picture.

Computer

Victor, Victor Technologies, Inc.
CPU Intel 8088
256 Kb RAM
2 × 1,2 Mb Floppy disk
or 10,6 Mb Hard Disk and 1,2 Mb Fl.d.
Monitor 12″
80 × 25 characters
Resolution 800 × 400 pixels

It has been found that commercially available numerically controlled milling machines are not suitable in this application. They are too overspecified for our purpose and the objectives of the CAPOD system cannot be fulfilled with such machines. Early on it became quite clear that for our purposes, a specially designed milling machine had to be developed. After some investigations, a design proposal, as illustrated by the schematic drawing, has been developed. The cutting is controlled by the same type of coordinates as were used during the measuring proce-

NC-Milling machine for CAPOD System



Principal Parts and Cost of the NC Milling Machine

3 stepper motors with control electronics	SEK	30,000
Cutting motor with converter and toolchuck	SEK	5,000
Chuck for the model	SEK	2,000
Gearheads, transmissions and bearings	SEK	18,000
Custom made parts and chassis	SEK	40,000
Assembling	SEK	8,000
	SEK	103,000
	US	$11,000

dure, i.e., the model will rotate in steps of one one-hundredth of a turn. The X and Y coordinates of the cutter are then controlled by coordinates corresponding to the X and Y coordinates of the measured and modified contour. The travel of this stroke is such that models of torsos and whole legs can be made. An important feature of the machine is the high speed which has been achieved through the use of stationary motors. By using stationary motors and transmissions to power the cutter, the moving parts have quite low mass, which gives a low inertia and allows high speed. It would be possible to cut a model of about 30cm length in two minutes. It is estimated that the fabricating cost of such a machine would be $10,000–11,000. Fifty percent of that cost is commercial parts—for instance, the control electronics for the stepper motors and the complicated transmissions. There are a few custom made parts, the whole chassis and assembling of the machine, which make up the other half of the cost.

The specification of the system has been worked out in co-operation with the orthopaedic technical departments in Gothenburg and Borås. They are also deeply involved in the educational program. The development work has come into a practical and detailed phase, and the whole team is very enthusiastic and anxious to fulfill the objectives and make the CAPOD system a successful system.

FOOTNOTE

[1] Paper presented for American Academy of Orthotists and Prosthetists Annual Meeting and Scientific Seminar, San Francisco, January 30–February 1, 1985.

AUTHOR

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TO: ORTHOTISTS AND PROSTHETISTS
FROM: EDITOR, *CLINICAL PROSTHETICS AND ORTHOTICS*
RE: INVITATION TO CONTRIBUTE TO THE *C.P.O.*

As professionals, we are obligated to do what we can to advance the state-of-the-art and share new developments with our colleagues. The most efficient way to transfer information, and the way that has the greatest impact, is through the written word. But, for many professionals, writing is a task that often becomes monumental to the point that we succumb to inertia. Writing, however, is not such a monumental task if we break it down into smaller, simpler tasks which we can complete one at a time.

The initial and most difficult problem every writer faces is how to organize the material. The quickest way to organize material is through use of an outline. In its most basic form, an article is divided into three parts—introduction, body, and conclusion. The introduction states the subject and gives pertinent background information that is necessary in order to understand the topic. The main body of the article then presents the topic in as much detail as possible. At the heart of every article is the intent to inform and answer a variety of questions. The body can include subheads, such as review of literature, method, clinical materials, discussion, and results. The conclusion restates the main points presented in the article.

Clinical Prosthetics and Orthotics addresses broad, philosophical issues, and as such invites a more subjective style. Each issue of *C.P.O.* centers on a main topic. Usually, an issue will contain a lead article, an editorial, and one or more technical articles pertaining to the topic. Authors are solicited by the Academy editorial board; however, *C.P.O.* also accepts unsolicited articles. Unsolicited articles need not cover the topic at hand and may be of a more technical and objective nature. All articles are submitted to the editor, a professional in the field, who checks every article for accuracy, terminology, format, and references. The articles are then forwarded to the publications staff at the Academy National Headquarters for production and printing.

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      Panton, Hugh J., B.S., C.P.O., "Considerations for Joints and Corset," *Newsletter . . . Amputee Clinics,* 8:3: June, 1975, pp. 1–3, 6–7.

   c. Lecture or Verbal Presentation
      1. Holmgren, Gunnar, "The PTB Suction Prosthesis" from the written material of a lecture delivered at the third of the "Strathclyde Bioengineering Seminars," 8–11 August, 1978.
      2. Wagner, F.W., Jr.: "Classification and treatment for diabetic foot lesions"; Instructional Course, American Academy of Orthopedic Surgeons, New Orleans, Louisiana, February, 1976.

   d. Personal Communication

      Irons, George, C.P.O., Personal communication, June 1977. Presently, Director of Research, United States Mfg., Glendale, California. Formerly, Research Prosthetist, Patient Engineering Service, Rancho Los Amigos Hospital, Downey, California.

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Letter to the Editor

Dear Editor,

Recent *Almanac* announcements of the Academy's plan for a college fund to create a chair in prosthetics and orthotics should be supported financially and politically by all practitioners who do not wish to lose control of our field to outside interests.

Alan Finnieston, CPO outlined a very real danger to our profession at a recent Midwest Chapter meeting. It is a potentially devestating combination of an unprecedented doctor glut and computerized manufacturing. Computerized manufacturing can be a great boon for us, providing we are not by-passed altogether through technological advances and an inability to keep up with them. As Alan pointed out, the next five years will see more changes in our field than have occurred in the last thirty.

If we wish to keep up with those changes and emerge through the next decade stronger than ever, then we must create the educational environment to hone our clinical skills, not our skiving knives. If we fail to rise to the occasion then we shall fall prey to this combination of computerized manufacturing and an ever-increasing medical professional pool.

The time has come to upgrade our minimal educational requirement to a baccalaureate in a related area. An associate degree in basket weaving is no longer acceptable. The time has come to increase the experience/internship requirement beyond a totally inadequate twelve months. The time has come to create America's first professional Doctorate program in prosthetics and orthotics. The time has come for a multitude of reasons, not the least of which is the continued vitality of our association through the years ahead.

Sincerely,
Edmond Ayyappa, CP

Calendar

1985

May 10–12, Third International Post-Polio Conference and Symposium on Living Independently with Severe Disability. Contact: Gini Laurie, Gazette International Networking Institute, 4502 Maryland Avenue, St. Louis, Missouri 63108.

May 31–June 1, American Academy of Orthotists and Prosthetists Continuing Education Conference 2-85, "Lower Limb Prosthetics," Sheraton Inn Airport, Pittsburgh, Pennsylvania.

June 11–12, Teaching Techniques for the Health Professional, Helen Hayes Hospital, Route 9W, West Haverstraw, New York 10993. Contact: John Sullivan, 914-947-3000, ext. 3325.

June 24–28, RESNA 8th Annual Conference on Rehabilitation Technology, "Technology—A Bridge to Independence," Peabody Hotel, Memphis, Tennessee. Contact: RESNA, Suite 402, 4405 East-West Highway, Bethesda, MD 20814, 301-657-4142.

July 18–20, American Academy of Orthotists and Prosthetists Continuing Education Conference 3-85, "Spinal and Seating Orthotics," Radisson Hotel South, Minneapolis, Minnesota.

September 6–7, American Academy of Orthotists and Prosthetists Continuing Education Conference 4-85, "Paraplegic Management," Boston, Massachusetts.

September 13–15, Fifth Annual *Advanced* Course in Lower Extremity Amputation and Prosthetics, Nassau County Medical Center, East Meadow, New York. Contact: Lawrence W. Friedmann, M.D., Chairman, Dept. of Physical Medicine and Rehabilitation, Nassau County Medical Center, 2201 Hempstead Turnpike, East Meadow, NY 11554; (516) 542-0123.

September 15–16, Ohio Chapter of the Academy Meeting, Resort Inn, Kings Island, Ohio. Contact: Jon Leimkuehler, CPO, 216-651-7788.

November 15–16, American Academy of Orthotists and Prosthetists Continuing Education Conference 5-85, "Powered Limb Prosthetics," Downtown Holiday Inn, Atlanta, Georgia.

1986

January 27–February 2, Academy Annual Meeting and Scientific Seminar, MGM Grand, Las Vegas, Nevada. Contact: Academy National Headquarters: 703-836-7118.

February 20–25, American Academy of Orthopedic Surgeons Annual Meeting, New Orleans, Louisiana.

April 8–11, Pacific Rim Conference, Intercontinental Hotel, Maui, Hawaii.

March 13–15, American Academy of Orthotists and Prosthetists Continuing Education Conference 1-86, "Spinal and Seating Orthotics," Birmingham, Alabama.

May 16–17, American Academy of Orthotists and Prosthetists Continuing Education Conference 2-86, "Disarticulation Prosthetics," Ann Arbor, Michigan.

July 18–19, American Academy of Orthotists and Prosthetists Continuing Education Conference 3-86, "Spina Bifida," Cincinnati, Ohio.

September 19–20, American Academy of Orthotists and Prosthetists Continuing Education Conference 4-86, "Powered Limb Prosthetics," Newington, Connecticut.

October 24–25, American Academy of Orthotists and Prosthetists Continuing Education Conference 5-86, "Lower Limb Prosthetics," Kansas City, Missouri.

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