CONTINUOUS PASSIVE MOTION FOLLOWING FIRST METATARSOPHALANGEAL JOINT SURGERY

Marc R. Bernbach, DPM

INTRODUCTION

Salter, in 1980, coined the term Continuous Passive Motion (CPM). His research was an actual extension of his previous work on the harmful effects of joint immobilization. Salter's theory worked on the premise that if intermittent motion was better for joints than immobilization, continuous motion should be even better than intermittent motion. The concept of passive motion was developed to avoid active muscle fatigue and the goal was to improve joint mobilization and regenerate damaged articular tissues.

Prior to Salter's investigations, some surgeons empirically suggested early motion for septic knee injuries as early as World War I. These early devices were patient-powered and custom counter balanced. The first known application of external power for limb and joint mobilization was by Nickel at Rancho Los Amigos Hospital in 1967 for the care of a rheumatoid patient following joint arthroplasty. However, early results of passive joint mobility were not encouraging and it was not until Salter's work that significant progress and encouragement for future work existed.

HISTOLOGY OF REPAIR

Synovial joints have extremely limited powers of healing and regeneration secondary to poor vascularity and poor cellular differentiation. The early healing process of a full-thickness injury penetrating beyond the subchondral region involves the following sequence. Initially hemorrhage and clot formation of the defect occurs. This is followed by capillary bud formation and subsequent fibro-vascular coverage of the defect area. Finally, mesenchymal cell infiltration occurs with later differentiation into a hyaline-type of tissue.

The initial repairing tissue is remarkably similar morphologically and histologically to hyaline articular cartilage. This remains so for at least 3-4 months following the initial injury. Type 2 collagen, the type found in normal hyaline cartilage, is initially found at the repair site. However, by one year there is a significant increase in the amount of type 1 collagen. At one year post injury the repair site more closely resembles fibrous tissue and is generally known as fibrocartilage.

Fibrocartilage repair is the standard and normal repair process for an articular, hyaline, cartilage injury. The repair site is often functional, however, the symptoms of degenerative arthritic disease may exist including pain, reduced joint mobility, edema, osteophytic production, joint effusion and progression of further articular degeneration.

Additionally, fibrocartilage was shown to lack normal muco-elasticity by the static compression test compared to hyaline cartilage. Thus, emphasis has been placed on improving the repair process so that the tissue more closely resembles hyaline tissue.

CONCEPT

Immobilization has been demonstrated to be deleterious to articular cartilage repair biochemically, biomechanically and morphologically. Clinically relevant effects of immobilization include: a decrease in joint fluid and, more importantly, a significant increase in cross linking of collagen fibers that occurs during joint immobility. When motion is increased, this cross linking decreases. Cross linking of collagen is believed to be responsible for tissue and related joint contractures. Furthermore, muscle atrophy, as well as bone atrophy are all clinically documented sequelae of immobilization.

Since early motion has been documented to produce better joint function and cartilage repair, the progression of research involved continuous passive motion to prevent the deleterious effects of immobilization. Salter demonstrated hyaline tissue in healing articular defects at three weeks in 3% of 36 defects in 9 animals whose knees were immobilized; 5% of 36 defects in 9 animals whose knees were permitted intermittent active motion and 44% of 36 defects in 9 animals whose knees were managed immediately postoperatively by continuous passive motion. Thus, CPM provided increased production of hyaline tissue as compared to immobilization. The gain being increased quality and quantity of normal hyaline-type tissue with CPM compared to joint immobilization.

The long-term histological effect was much superior with CPM compared to immobilization, as poorly-mobilized joint defects reverted back to a fibrocartilage-type of tissue within one year of injury. The collagen type of the CPM repair had a greater type 2 collagen content, the type found in hyaline articular cartilage. Furthermore, continuous passive motion produced histological evidence of faster long term healing of fractures within cartilage. The healing tissue more closely resembled hyaline articular tissue than the repair associated with immobilization. Additionally, CPM in the first postoperative week prevented joint adhesions and decreased the occurrence of late post-traumatic arthritis. There is also significant evidence of joint preservation and decreased progression of joint deterioration when CPM is utilized following septic arthritis. CPM has also been demonstrated to increase the clearance of hemarthrosis twice as fast as immobilization.

Clinically, the potential primary advantages of CPM are: obtaining increased joint mobility at a faster rate; limiting postoperative pain and edema; and preventing the occurrence of deep venous thrombosis.

Although increased joint mobility occurs at a substantially faster rate, there is some evidence to indicate the ultimate range of motion in six months to one year may be equal. Postoperative pain has been demonstrated to be decreased with CPM and this is postulated to be secondary to a gate-control theory where continual proprioceptive impulses block pain transmission. It has also been theorized that continuous passive motion may decrease the incidence of deep venous thrombosis and pulmonary embolism secondary to the pumping action of the involved musculature and resultant increased venous flow.

INDICATIONS

The indications for continuous passive motion of the foot and ankle include open reduction of intra-articular fractures, open reduction of diaphyseal and metaphyseal fractures, and capsulotomy-arthrotomy and joint salvage procedures of the ankle and foot for post-traumatic arthritis and degenerative joint disease. Additional indications include synovectomy for rheumatoid arthritis, surgical release of extra articular contractures, and prosthetic implantation of the ankle or first metatarsophalangeal joint.

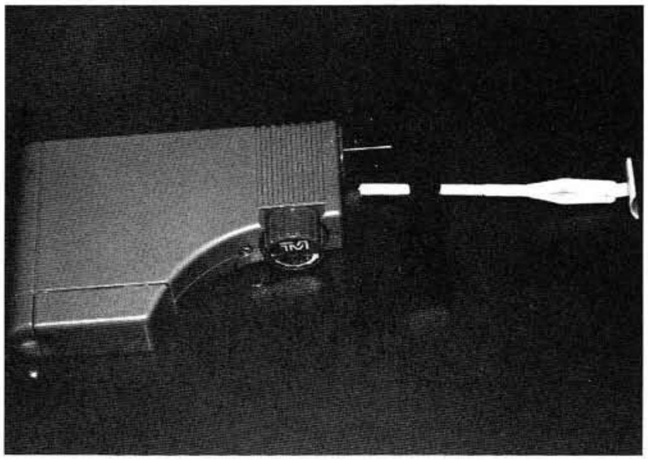

Fig. 1. A Continuous Passive Motion machine. Note the three essential components, a motor (battery or electric), limb carriage, and controls.

MECHANICS

A CPM machine consists of three essential components, a motor (battery or electric), limb carriage, and controls (Fig. 1). The major variables include the rate of motion, with the range being anywhere from 40-60 seconds per cycle, the range of the motion arc and also the position of the motion arc relative to the normal joint axis.

Currently, no CPM device exists which is exclusively designed for the joints of the foot. However, several excellent adaptations of hand and ankle-type devices do exist for the first metatarsophalangeal joint. Future development for a device specifically designed for the first metatarsophalangeal joint has been proposed and is scheduled for production.

The ideal device will be easily controlled by both the patient and the physician. The arc and axis of motion should approximate normal joint range of motion. Furthermore, it should be simple and designed to promote patient acceptance and portability of the machine.

CLINICAL APPLICATION

The primary experience and emphasis of this discussion involves clinical use of CPM for first metatarsophalangeal joint disorders. The concepts of continuous passive motion being understood, the potential benefits are significant when applied to first metatarsophalangeal joint surgery.

There are three primary areas of first metatarsophalangeal joint surgical repairs relevant to CPM, joint salvage procedures, first metatarsophalangeal joint prosthetic implantation procedures, and hallux abducto valgus surgical repairs.

Joint salvage surgical procedures (Watermann, etc.) often include subchondral drilling of articular defects in an attempt to regenerate a gliding surface. Historically, a fibrocartilage repair was considered clinically less than adequate; however, CPM may alleviate some of the dissatisfaction with joint salvage procedures due to increased hyaline articular cartilage at the defect site.

Joint prosthetic procedures and hallux valgus surgery present with clinical problems including joint edema as well as postoperative stiffness. The benefits of CPM with these procedures has been discussed earlier.

CPM should be applied for at least 6-8 hours per day to obtain maximum effect. Shorter periods have been shown to provide some benefit, but less than optimal results were obtained. Therapy should be instituted immediately postoperative, or at least during the first postoperative week (Fig 2). If CPM is applied after one week postoperatively, its effect is significantly reduced. Continuous passive motion should be utilized from one to three weeks duration. However, some studies indicate no additional gain after one week of therapy.

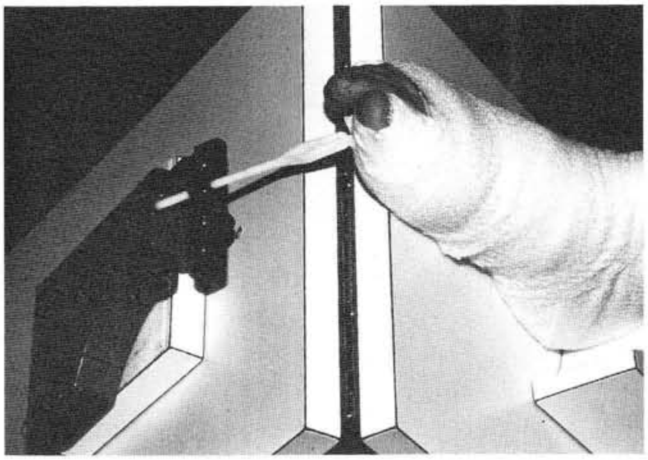

Fig. 2. Continuous Passive Motion should be instituted immediately postoperative, or at least during the first postoperative week.

CONCLUSION

Continuous passive motion in relation to first metatarsophalangeal joint surgery can provide several benefits including: increased joint mobility, faster healing, reduced edema and earlier return to normal activity. Complications are minimal and are easily controlled by proper patient education and selection. Technology for first metatarsophalangeal joint CPM is progressing and should become even more functional with further research.

BIBLIOGRAPHY

Bunker TP, Potter B, Barton MJ: Continuous Passive Motion Following Flexor Tendon Repair. *J Hand Surgery* 14:4, 1989.

Guidera KJ, Hontas R, Ogden JA: Use of Continuous Passive Motion in Pediatric Orthopedics. *J Pediatr Orthop* 10:1, 1990.

Mooney V, Stills M: Continuous Passive Motion With Joint Fractures and Infections. *Clin Orthop* 18:1, 1987.

Salter RB, Bell RS, Keeley FW: The Protective Effect of Continuous Passive Motion on Living Articular Cartilage in Acute Septic Arthritis. *Clin Orthop* 159: 9, 1981.

Salter RB, et al.: Clinical Application of Basic Research on Continuous Passive Motion For Disorders and Injuries of Synovial Joints: A Preliminary Report of a feasibility study. *J Orthop Res* 1:3, 1984.

Shimizu T, Videman T, et al.: Experimental Study on the Repair of Full-Thickness Articular Cartilage Defects: Effects of Varying periods of Continuous Passive Motion, Cage Activity, and Immobilization. *J Orthop Res* 5:2, 1987.

Stienstra JJ: Continuous Passive Motion-A Podiatric Overview. *J Foot Surg* 26:1, 1987.