CHAPTER **50**

# PRINCIPLES OF CONTINUOUS PASSIVE MOTION: The Basis for Clinical Investigation in Foot and Ankle Surgery

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## INTRODUCTION

Tradition has dictated that rest be a significant part of a treatment regimen for musculoskeletal conditions. The idea that rest is a necessary treatment for musculoskeletal conditions is indeed a widely accepted standard, described within the Corpus Hippocraticum[1], promoted by Pare[2], and prescribed in large quantities by the great orthopedic surgeon Sir Hugh Owen Thomas who stated that immobilization must be "complete, prolonged, uninterrupted, and enforced."[3] However, Salter, an avid proponent of continuous passive motion after trauma or surgery, explains that treatment by rest is based "on empiricism rather than on scientific investigation."[4]

There is a general trend among orthopedists and some surgeon specialists including podiatric surgeons to resume mobility quickly after surgery or injury, rather than prolonged rest and immobilization. Juste Lucas-Championniere, a French surgeon who practiced around the turn of the 20th century, promoted motion and massage rather than rest to prevent joint contracture and muscle atrophy.[5] He believed that splinting joints caused them to be stiff and subject to "irrecoverable damage," and that "every movement which is not injurious by reason of its amplitude favors repair." Empirical evidence for motion rather than rest for limb afflictions accumulated throughout the early 20th century and became more and more compelling. The middle part of the 20th century saw the development of the Arbeitsgemeinshaft fur Osteosynthesesefragen (AO/ASIF), a group of Swiss surgeons and later international study group for internal fixation methods. The fundamental principles of the AO method demands early full, active, pain-free mobilization of muscles and joints. As stated in the opening section of their Manual of Internal Fixation, "Fracture disease is a clinical state which is manifested by chronic oedema, soft-tissue atrophy, osteoporosis, and joint stiffness. Every type of fracture treatment must therefore encompass the treatment not only of the fracture but also of all the associated local reactions."[6]

Extensive investigation has been carried out on the effects of rest on joints and periarticular structures. Muscle atrophy due to disuse from forced immobilization, the so-called "plaster entrapment syndrome," is a well recognized malady described by numerous authors throughout the medical literature.[7-9] In 1933, Ely and Mensor described thinning and fibrillation of articular cartilage in immobilized normal canine ankle joints.[10] In 1960, Salter demonstrated that immobilization of a rabbit knee joint under continuous compression, whether through a delivered compressive force or through forced position, resulted in pressure necrosis of the joint cartilage.[11] Several years later Salter et al again described this "obliterative degeneration of articular cartilage" secondary to the deleterious effects of immobilization on the articular cartilage of rabbit knee joints.[12] Evans[13] and later Hall[14] described the deleterious effects of immobilization of the knee joints in rats, with descriptions of cleft formation, matrix fibrillation, flattening of articular cartilage and synovial adherence.

Other investigators have evaluated the effects of motion of joints on articular and periarticular structures, including extensive research by Salter and colleagues. Saaf, in 1950, reported a temporary increase in the size and number of chondrocytes in an exercised guinea pig shoulder joint.[15] Hohl and Luck, in 1956, demonstrated a markedly increased range of motion and fewer intraarticular adhesions in the exercised knee joints of six monkeys with intraarticular fractures when compared with those that were immobilized after injury.[16] Based on empirical and now scientific evidence, motion, therefore, is in some way beneficial for healing joints.

Salter showed the development of articular defects in rabbit knee joints immobilized both with and without compression which resulted in degenerative arthritis in both cohorts.[12,17] Through observation of the deleterious effects of immobilization of synovial joints including persistent pain and stiffness, disuse osteoporosis, and late degenerative arthritis along with his basic scientific research, the biologic foundations for continuous passive motion of synovial joints was developed. The logical extension of intermittent motion for cartilage health and regeneration, continuous motion, was initiated by Salter in 1970.[18] The motion was passive because active motion of a painful, stiff joint is subject to factors such as fatigability of skeletal muscle, patient compliance, and pain tolerance issues. He also believed that this continuous, passive motion should be possible to apply immediately after injury or operation without causing the patient significant pain. Subsequent research on continuous passive motion of synovial joints was summarized by Salter in 1994, citing the regeneration of hyaline articular cartilage in 52% of full-thickness defects treated with CPM compared with 18% of immobilized joints, healing of 80% of intra-articular fractures treated with CPM compared with 20% treated through either immobilization of intermittent active motion, double the rate of clearance of a hemarthrosis treated with CPM, increased breaking strength of tendon fibers treated with CPM, and many more positive effects of CPM when compared with controls or other forms of immobilization.[18] Salter went on to state that "The relative place of rest and of motion is considerably less controversial on the basis of experimental investigation than on the basis of clinical empiricism."[4]

Joint cartilage health and regeneration to be an active area of research and application. However the major clinical use of CPM today is in rehabilitation of joints that are prone to stiffness following trauma or surgery such as the knee, elbow, ankle, and small joints of the hand. This adjunctive clinical application has stemmed from Salter's hypothesis of the three main beneficial effects of CPM in vivo: enhanced nutrition to articular cartilage, stimulation of pluripotent mesenchymal cells to differentiate into cartilage rather than another tissue type, and accelerated healing of cartilage and periarticular tissues. These subsequently validated effects, when coupled with the idea that the therapeutic value of rest in the course of healing musculoskeletal tissues still remains controversial,[18] makes CPM an attractive treatment modality to treat and prevent arthrofibrosis.

## CPM AND ARTHROFIBROSIS

Many if not most practitioners see clinically apparent "joint stiffness" as a static form of fibrosis, not as a continuum of arthrofibrosis. It has been theorized that there is an evolution of joint stiffness that follows a pattern after joint injury (including iatrogenic disruption) if there is no intervention. This pathophysiology of joint stiffness, as described by Driscoll and Giori, includes four stages: bleeding, edema, granulation tissue, and fibrosis.[19] The first stage, bleeding, occurs within minutes of surgery or trauma, causing joint capsule distention and pressure on pariarticular tissues. The joint fills with fluid to its maximal capacity. Attempts to flex or extend the joint creates high hydrostatic pressures within the joint, which will resist motion and cause severe pain due to tension on capsular structures. Consequently, the natural tendency is to maintain the joint at the position of maximal intraarticular volume and minimize motion through "splinting." Within a few hours edema sets in, resulting in increased swelling in the subcutaneous tissues against an already tensed joint capsule, further reducing the compliance of the capsular tissue. The result is a physical fluid and fat barrier to joint motion.

The formation of granulation tissue is the next stage in the development of arthrofibrosis and ensues within a few days to weeks following trauma or surgery. The significance is the replacement of fluid by a denser tissue, albeit a loosely organized but highly vascular tissue. The finaly phase is fibrosis, which is hallmarked by organization of the granulation tissue and formation of a dense scar.

If stiffness were a pathology that follows a definable/traceable course without intervention, then it should be apparent that intervention should have some effect on the course. This can be likened to the development of ankle arthritis after syndesmotic disruption; without intervention the post-injury course is known from the outset. If after injury the amount of intraarticular bleeding is minimized and intra- and periarticular fluid collection is prevented, then granulation tissue should be minimized and consequently the extent of fibrosis should be minimized. Exercising the limb and affected joint can assist in milking away the edema resulting from inflammation by affecting periarticular hydrostatic pressures and encouraging venous and lymphatic return. Immediate range of motion consequently serves a dual purpose: fluid removal and motion preservation.

The theoretical clinical advantages of CPM that make it useful in acute and subacute rehabilitation include early functional range of motion, a decrease in postoperative pain and swelling, decrease in joint adhesions, and a decrease in the incidence of deep venous thrombosis. The applications in the lower extremity are numerous. For example, CPM can be applied postoperatively for prolonged joint stiffness or capsular adhesions, post intra-articular defect or fracture reduction and fixation, post joint arthrotomy or arthroplasty, prosthetic joint replacement, or ligamentous reconstruction. It becomes a mystery then that a thorough description of the application of CPM to a series of patients in the podiatric literature is limited to a single report by Kaczander, who applied continuous passive motion to 100 patients, and was able to return patients to normal footgear an average of 10 days earlier.[20]

## A MODEL FOR CLINICAL INVESTIGATION AFTER FOOT AND ANKLE SURGERY

The authors have designed a study protocol to evaluate the efficacy of continuous passive motion (CPM) after ankle surgery. The study has three main hypotheses:

1. Continuous passive motion of the talocrural joint postoperatively results in an increased maximal (range of) motion after therapy.
2. Continuous passive motion of the talocrural joint postoperatively results in reduced pain.
3. Continuous passive motion of the talocrural joint postoperatively results in earlier return to function.

To evaluate the first hypothesis, preoperative range of motion measurements are obtained prior to joint preserving procedures on the human ankle joint (e.g., lateral ankle ligament repair, osteochondral lesion drilling, microfracture, or chondral grafting, arthroscopic synovectomy, etc.) in a study population. CPM is then instituted postoperatively in a randomized cohort of this population regardless of operation. The joints of the CPM group are exercised according to a standardized protocol using the Artromot SP-2 Model CPM Machine, while the non-CPM cohort is managed with restricted motion according to acceptable practice standards. Serial postoperative range of motion measurements are obtained at specified intervals (1 week, 2 weeks, 1 month, 2 months and conclusion) until the study conclusion (6 months postoperatively). When there is reduced preoperative ankle motion the results are compared with preoperative values for both the affected and contralateral unaffected limb. In cases of "normal" ankle range of motion results are compared with the preoperative measurements of the ipsilateral limb for statistical analysis.

There are two types of variables to analyze: categorical and continuous. To statistically evaluate relationships between two categorical variables (for example, procedure and preoperative range of motion/postoperative range of motion), Pearson's chi-square test is used. For statistical comparison of continuous variables (i.e., time to achieve a stated range of motion goal), a two-sample t-test will be performed with the hypothesis being that the variable (time to preoperative range of motion) has the same mean within the two defined groups (CPM versus non-CPM). The results from evaluation of categorical relationships may provide insight into which procedures may benefit most from CPM and in which procedures CPM shows no benefit. Continuous variable analysis may disprove the hypothesis that CPM can actually decrease the time to reach a stated physical goal.

The second hypothesis requires a patient questionnaire for assessment of pain levels. The modified McGill Pain Questionnaire (SF-MPQ) is used and includes 3 major classes of word descriptors: sensory, affective and evaluative, as well as intensity scale. These questionnaires are completed preoperatively and postoperatively on all patients in the study at the stated intervals (prior to surgery, upon completion of the course of CPM, and at the conclusion of the study). The surveys are administered and graded according to published methods.[21]

The third hypothesis also requires a questionnaire, which consists of a modified Medical Outcomes Study (MOS) Short Form, or SF-36. The traditional SF-36 includes several questions regarding general health and energy/vitality (emotional/psychologic health assessment) while the current study is interested in physical health, role limitations, and pain. These surveys are administered along with the McGill questionnaire and graded according to published methods.[22]

Clearly there is merit to the use of motion early on in the treatment of articular injury, whether traumatic or iatrogenic in origin. There is even further argument for early motion given the association between immobilization and certain pathologic processes such as arthrofibrosis, "cast disease," deep venous thrombosis, and so on. The purpose of this study is to assess the validity of continuous passive motion after ankle surgery and develop recommendations regarding its use.

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