Hand Rehabilitation Utilizing a Continuous Passive Motion Device following a Tenolysis, Arthrolysis, Capsular Release or Post-Traumatic Stiffness; A Review

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Background
Post-operative rehabilitation of the hand consists of a period of passive motion (PM) to prevent adhesions, the detrimental effects of immobilization, reduce pain, reduce inflammation and increase range of motion to a functional level. Continuous passive motion (CPM) devices have been used routinely as a PM modality.

Objectives
To determine, with evidence from peer-reviewed journals, the optimal rehabilitation strategy, including the use of CPM, after a repair, release of a contracted joint or tissue, and post-traumatic stiffness (burn, fracture, mutilation, tendon repair and ligament repair).

Search strategy
The search included MEDLINE (1980 to 2005), JBJS (1974 to 2005), AJSM, Sage Publications (1976 to 2005), Lippincott Williams & Wilkins online journals, Springerlink.com online journals, NCBI.nlm.nih.gov (database), elsevier.com (Elsevier Health Science Periodicals) and reference lists of articles.

Main results
Twenty studies following a release of a contracted joint or tissue were included. Data were not pooled. In all studies, CPM demonstrated either statistically significant (11 studies) or positive functional (9 studies) outcomes for subjective and objective measures. The outcomes evaluated were overall function, range of motion, compliance, and cost effectiveness. CPM was superior to physical therapy alone or contracture splinting alone (6 studies). Six studies reported on duration of CPM use. Five studies reported six or more weeks of use and one study reported four weeks of use in order to reach significant results.

Summary/Discussion
Prior to 1989 there were few reports on the use of CPM following the surgical release of a joint contracture or the use of CPM post-trauma. Frykman[35] reported statistically superior outcomes ($p<.05$) on the use of CPM for stiff MP and PIP joints of the hand for posttraumatic ankylosis in 1989. CPM for six weeks in duration was tried after a vigorous hand therapy program had failed or after a previous surgical intervention without CPM had failed. Bradley[12] reported significant positive results with CPM use for 10 hours per day after arthroscopy and manipulation for primary adhesive capsulitis of the shoulder in 1991. Also in 1991, a retrospective study by Breitfus[13] found CPM to be superior to physical therapy and a splinting program. The author also looked at start time and found superior results were seen when CPM was started within 48 hours following the surgical procedure. A second retrospective study was done by Schindler[126] between1982-1988 and found CPM the only rehabilitation variable of value. CPM was initiated following an arthrolysis procedure for a contracted joint and resulted in a statistically significant improvement ($p<0.01$) both in range of motion and function (88% of CPM users improved more then 10^0 while only 29% of non users had similar success).

A study by Gates[41] in 1992 compared physical therapy to a CPM (six weeks) protocol following a release of a joint contracture. The CPM group improved a mean of 47° compared to only 25° in the physical therapy group. Ippolito[52] also reported functional improvements with CPM after six weeks of use compared to a similar series who only utilized physical therapy in 1999. The importance of an intensive early CPM program was emphasized by both Olivier[99] and Bennet[10] following surgical releases in 2000. Olivier[99] had ninety-one patients and Bennet[10] had sixty-eight patients who reached statistically significant ($p<0.05$) gains in range of motion and function after a capsulotomy and post op use of CPM. Aldridge[4] compared the efficacy of CPM to a traditional splinting program in 2004. Splinting programs following a surgical release of a stiff joint had been the standard of practice with many surgeons. This study of 106 joints joins the growing body of research demonstrating statistically superior results with CPM ($p=0.27$) over splint and physical therapy only programs.

Nicholson[85] found that CPM following an arthroscopic release was equally effective across five identified etiologic groups as well as providing pain relief in 2003. Recent studies by Bae & Waters[8] in 2001, Tsionos[135] in 2004, and Wu[143] in 2003 confirm that CPM following a joint release to the shoulder, elbow or hand is needed to reach functional range of motion.

The average period of use was six weeks following a surgical release or manipulation of the shoulder, elbow or hand in order to reach statistically significant improvements in range of motion and function. Only one author out of sixteen authors mentioned that they used CPM for only 4 weeks. Actual duration depended on the patient. If the patients range of motion stabilized (no increase or decrease) then CPM was reduced or discontinued. If a loss of motion was detected or continued gains seen then CPM was continued.

POSTOPERATIVE HAND CPM FOLLOWING JOINT SURGICAL RELEASE, TENOLYSIS, ARTHROLYSIS, OR POST-TRAUMATIC STIFFNESS OF THE HAND

INTRODUCTION

CPM after the surgical release of a joint contracture, other soft tissue or post-traumatic stiffness has been used extensively in the hand, elbow, and shoulder.[60] Clinical studies have demonstrated that CPM compared to physical therapy alone, CPM compared to splinting alone or CPM combined with physical therapy have resulted in superior statistical outcomes over programs without CPM.[4,13,14,35,41,52]

The initial goal of therapy following a surgical release of a contracted joint or other soft tissue and post-traumatic stiffness is to maintain the range-of-motion gained after the release or to improve range-of-motion. If passive motion is not started within the first 48 hours following the release the prognosis for improvement is significantly diminished.[13] O'Driscoll and Giori[93] have demonstrated that CPM immediately following a surgical release acts to pump blood and edema fluid out of the joint and periarticular tissues. The reduction of these fluids from a synovial joint reduces the risk of post-surgical joint stiffness. A contracted joint typically has an inflammatory component which can be aggravated by the surgical procedure itself resulting in limited or no improvement in range-of-motion. Salter,[122] Kim,[56] Kreder[59] and Moran[82] have all shown that CPM has reparative effects on inflamed joints. However, until recently the mechanism by which CPM acts as an anti-inflammatory agent was unknown. Recent studies by Gassner,[40] Lee,[63] Xu[144] and Ferretti[33] have helped explain the molecular basis for the beneficial effects of CPM on an inflamed joint. A CPM device by applying cyclic tensile stress on the involved joint for an extended time counteracts the effects of the inflammatory agents even better than immobilization.

The efficacy of CPM following a joint release in the hand is clearly demonstrated in the following peer-reviewed studies. CPM leads to greater functional outcomes, greater ROM, improved healing by acting as an anti-inflammatory agent and higher patient satisfaction. The duration of CPM use is determined by the severity of the contracture and as long as improvements are seen.

EFFICACY OF PEER-REVIEWED CPM STUDIES FOLLOWING A POST-SURGICAL RELEASE OR POST TRAUMATIC STIFFNESS

A search in peer-reviewed medical journals for clinical studies involving the use of continuous passive motion following the release of a contracted joint or soft tissue revealed five hand, ten elbow, and four shoulder studies. In all studies the primary finding was that the use of CPM for passive motion following a surgical joint release resulted in both objective and subjective positive outcomes for overall function, range of motion, compliance and cost effectiveness.[4,8,10,12,35,41,52,60,85,99,100,126,136] Postoperative rehabilitation protocols that included CPM are proven to be statistically more effective than protocols that did not include CPM (compared to physical therapy, splinting, and patient directed exercises).[4,13,35,41,52,126]

HAND

1. Frykman GK, Matsushima D, Waylett-Rendall J, Unsell RS: CPM improves range of motion after PIP and MP capsulectomies; A controlled prospective study. American Society for Surgery of the Hand, 44th annual meeting: September, 13-16, 1989.

Continuous passive motion (CPM) has been beneficial following joint surgery and has become a popular postoperative therapy. We are reporting on a controlled prospective study using CPM following capsulectomy of MP and PIP joints of the hand.

All patients had capsulectomy of one or more joints for posttraumatic ankylosis. All had failed to improve in range of motion with a vigorous hand rehabilitation program and several had failed a previous capsulectomy procedure that did not include postoperative CPM. Except for CPM, all

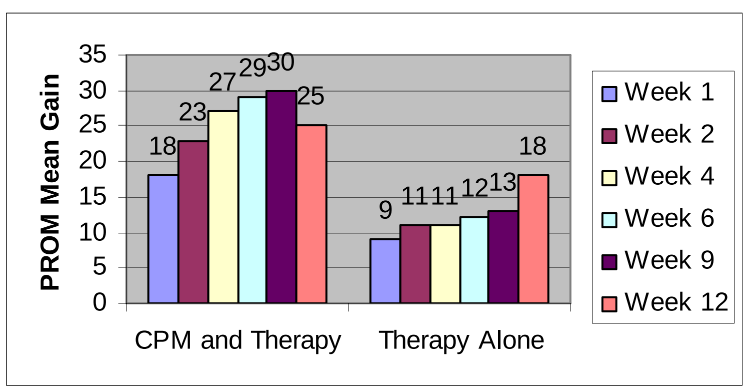

Figure 1
ROM gains were statistically superior when CPM was part of the post-op protocol.

patients had the same vigorous postoperative hand therapy program begun as soon as possible (usually within one day) postoperatively. They were followed for six months postoperatively. In the study group CPM was used for an average of six weeks postoperatively. Fifty-one joints (30 PIP and 27 MP) were studied in 31 patients. Overall the mean gain in range of motion from preoperative values is found in Figure 1. The gain in passive ROM was grater than active ROM. The pain was less postoperative in the CPM group. There were no significant complications from CPM use.

Patients who used CPM following MP and PIP capsulectomy had a statistically significant (P< .05) gain in postoperative passive ROM and active range of motion compared to a conventional hand therapy program.

2. Barillo DJ, Harvey KD, Hobbs CL, Mozingo DW, Cioff WG, Pruitt BA: Prospective outcome analysis of a protocol for the surgical and rehabilitative management of burns to the hand. *Plast Reconstr Surg* **100(6):1442-51, November 1997.**

Treatment protocols for the management of burned hands are essential for integrating team efforts and achieving optimal functional results. Standard protocols are especially useful during mass casualty incidents, when the admission of multiple patients with large burns and/or associated injuries may reduce the priority usually accorded the hands. We prospectively evaluated a surgical and rehabilitative treatment protocol for burned hands during a mass casualty incident, after which 43 burn patients with 82 burned hands were admitted to one burn center. Soft-tissue management was individualized to achieve, if possible, wound closure within 14 days, and included the use of topical antimicrobials, cutaneous debridement and/or tangential excision, biologic dressings, and split-thickness autografts.

Range of motion therapy was based on daily measurement of active motion of the metacarpophalangeal joints. Static splinting alternating with continuous passive motion every 4 hours was utilized for sedated patients. Continuous passive motion alternating with active ranging and night splinting was utilized for metacarpophalangeal flexion <70 degrees. Active ranging and progressive resistance was utilized for metacarpophalangeal flexion ≥ 70 degrees. Sixty-four hands required excision and grafting, with 89 percent having at least one autografting procedure completed by postburn day 16. Total active motion of the hands treated averaged 220.6 degrees on discharge and 229.9 degrees at 3 months after injury. Mean hand grip strength was 60.8 pounds at discharge and 66.0 pounds at 3 months after injury. Adherence to a standard hand burn protocol resulted in timely wound coverage and recovery of hand function for a large group of patients treated at a single burn facility after a mass casualty incident.

3. Weinzweig N, Jones A: Continuous Passive Motion Therapy in functional rehabilitation of the injured hand. Abstract, *American Society for Surgery of the Hand, 44th Annual Meeting*, **September 1989.**

Continuous Passive Motion (CPM) has proven extremely encouraging in functional rehabilitation of the hand following Zone II flexor tendon repairs. Over the past two years, we evaluated the role of CPM in a variety of traumatic hand conditions including thermal injuries, flexor and extensor tendon repairs and tenolysis, capsulotomies, replantations and intra-articular fractures. Total active motion (TAM) was calculated and values placed on a grading scale according to quality of joint movement.

In 250 burned digits, excellent results were achieved in 73%, good in 25%, and fair in 2% with a mean of 240 degrees or 92% normal TAM. CPM was well tolerated in all patients with a decrease in pain allowing other kinetic areas to be addressed and did not disrupt skin grafts. In 37 injured digits requiring flexor tendon repair, excellent results were contained in 41%, good in 54%, and fair in 5% with a mean TAM of 229 degrees or 84% normal TAM. In a more limited series of patients, results following dorsal capsulotomies were 20% excellent and 20% good. Following extensor tendon repair there were 20% excellent, 40% good, and 20% fair and 20% poor. While this is a preliminary on-going study with a limited patient population, CPM may play a significant role following dorsal capsulotomies, replantations and intra-articular fractures. Further assessment is needed to maximize CPM's role in these and other hand afflictions.

4. Osterman AL, Bora FW, Skirven T: The use of continuous passive motion in hand rehabilitation. Proceedings of the 42nd annual meeting of the American Society for Surgery of the Hand. San Antonio. 1987.

The authors found CPM to be helpful in increasing ROM after capsulotomy of the finger PIP joints.

5. Adams KM, Thompson ST: Continuous Passive Motion use in hand therapy. *Hand Clinics* **12 (1): 109-121, February 1996.**

"Continuous passive motion (CPM) may be used to enhance healing, prevent complications after injury or surgery, correct joint contracture, control pain, facilitate neuromuscular re-education, and augment therapy sessions. CPM helps maintain the potential for motion by moving tissues while healing occurs, preventing adhesions and contractures. In fact, CPM was found to speed wound healing and recovery. CPM is of most benefit immediately post-injury or post-surgery, when active range of motion (ROM) is contraindicated or inhibited by pain or fear. Because it provides controlled, predictable, and fixed passive ROM at a constant rate, patients are more comfortable and anxiety is reduced compared with intermittent, unpredictable manual ROM therapy.

Table 1: Protocol for flexor tendon repair

Day 1	⇒ Day 1 Dorsal extension block dynamic splint postoperatively. ⇒ Wrist in flexion. ⇒ Metacarpophalangeal joint 60 degrees flexion. ⇒ The splint allows full interphalangeal extension. ⇒ The wrist is flexed 20 to 30 degrees.
Day 2	Dressing change. Therapist instructs active extension, passive flexion, and daily exercises.
Day 7-10	Begin CPM machine with metacarpo-phalangeal (MCP) block 20 minutes every hour when awake, lowest rate, 3–5 second pause.
Day 14	Decrease MCP block 20 degrees
Day 21	Decrease MCP block 20 degrees more, start non resistive active exercise.
Day 22	Begin active resistive exercises.
Day 42	Start Baltimore Therapeutic Exercise- work simulator, as necessary. Cylindrical casting (changed three times a week) if necessary to restore extension.

Table 2: Protocol for tenolysis

⇒ The initiation of CPM immediately postoperatively depends on the condition of the tendon observed during the operation.

⇒ The CPM machine is applied in the recovery room.

⇒ Adequate analgesic is prescribed.

⇒ Regional anesthesia allows the patient to see immediately the range of movement possible.

⇒ The patient is discharged home with the CPM machine.

⇒ Some patients may be given a transcutaneous electrical nerve stimulation (TENS) unit to control the pain.

⇒ The patient returns to the office the next day for the therapist to supervise treatment.

⇒ The patient can have some active movement as per instruction.

ELBOW

6. **Aldridge JM, Atkins T, Gunnerson EE, Urbaniak JR; Anterior release of the elbow for extension loss.** *J Bone Jt Surg* **86A(9):1955-60, 2004.**

The purpose of this study was to report the outcomes of surgical correction, predominantly with an anterior release, of elbow flexion contractures. In addition, the author's evaluated the efficacy of continuous passive motion use for four weeks or more depending on the severity of the contracture. The author's retrospectively reviewed the outcomes of 106 consecutive patients who had undergone anterior elbow release for the treatment of a flexion contracture between July 1975 and June 2001. Twenty-nine patients were excluded because they had been followed for less than twelve months, leaving a study group of seventy-seven patients. Postoperatively, fifty-four of the seventy-seven patients were treated with continuous passive motion and the other twenty-three patients were treated with extension splinting. The average duration of follow-up was thirty-three months. The average patient age was thirty-four years. The results were evaluated on the basis of both preoperative and postoperative radiographs as well as clinical measurements of elbow motion, all performed by the same examiner using the same large (47-cm-long) goniometer.

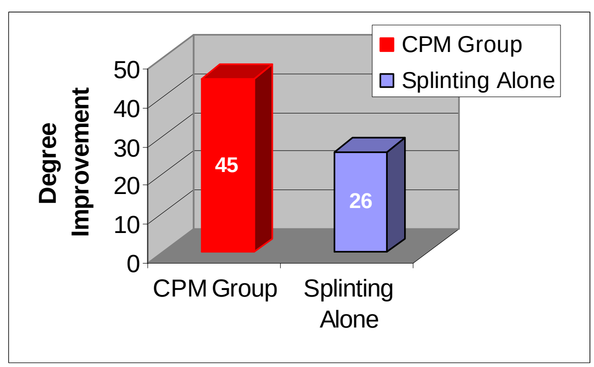

Figure 2
CPM following a surgical release offers statistically superior functional outcomes over splinting and physical therapy without CPM. (p=0.27)

Results: The mean preoperative extension in the seventy-seven patients was 52°, which decreased to 20° postoperatively. The mean flexion increased from 111° preoperatively to 117° postoperatively, and the mean total arc of motion increased from 59° to 97°. The total arc of motion in the patients treated with continuous passive motion increased 45°, compared with an increase of 26° in those treated with extension splinting (P=0.27).

The primary result is the release of a pathologically thickened anterior elbow capsule through a predominantly anterior approach to correct diminished elbow extension is a safe and effective technique. Furthermore, compared with splinting in extension alone, the utilization of continuous passive motion during the postoperative period resulted in a statistically significant increase in the total arc of motion (Figure 2).

7. **Ippolito E, Formisano R, Caterini R, Farsetti, P, Paneta F; Resection of elbow ossification and continuous passive motion in postcomatose patients.** *J Hand Surg* **24A(3): 546-53, 1999.**

Heterotopic periarticular ossifications were surgically excised in 16 elbows of 14 traumatic brain injury patients an average of 18.9 months (range, 4-67 months) after the end of coma. In 11 elbows the ulnohumeral joint was ankylosed in a position that ranged from 0° to 100° of flexion (group 1); in 5 elbows the arc of flexion ranged from 10° to 25° (group 2). Full pronation and supination were present in 15 of the elbows; in 1 the radiocapitellar joint was fixed at 30° of pronation by a partial ossification of the interosseous membrane. The arc of flexion attained after surgery averaged 115° (range, 90° to 145°) in the group 1 elbows and 128° (range, 115° to 140°) in the group 2 elbows. In an attempt to prevent postoperative loss of motion and recurrence of ossification, continuous passive motion was applied to the affected elbow for 6 weeks before starting a fully active rehabilitation program. All the patients were examined at regular intervals after the surgery. The follow-up period ranged from 12 to 60 months (average, 30.7 months). During the follow-up period, all the elbows showed improvement in range of motion and the arc of flexion averaged 95° (range, 30° to 135°) in the group 1 elbows and 116° (range, 80° to 145°) in the group 2 elbows.

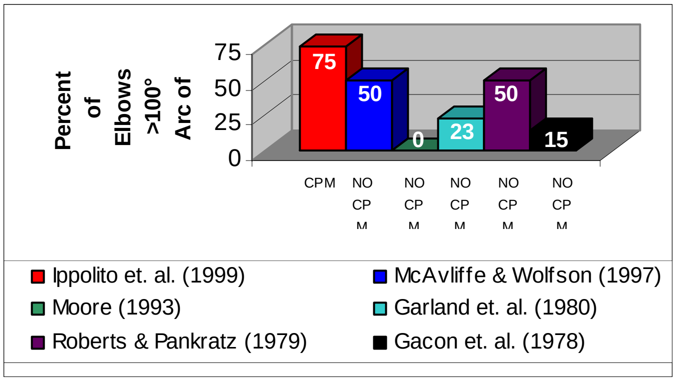

Figure 3
CPM is a more effective in reaching functional ROM then a rehab program with out CPM following the release of a stiff joint.

The primary finding is that the author's results were superior with CPM when compared to previous investigators who did not use CPM for 6 weeks postoperatively (Figure 3).[36,37,70,81,103]

8. **Gates H, Sullivan F, Urbaniak J: Anterior capsulotomy and continuous passive motion in the treatment of post-traumatic flexion contracture of the elbow; A prospective study.** *J Bone Jt Surg* **74A(8): 1229-39, 1992**.

Thirty-three patients who had a post-traumatic flexion contracture of the elbow were managed consecutively with anterior capsulotomy without tenotomy of the biceps tendon or myotomy of the brachialis muscle. The first fifteen patients (Group I) did not receive continuous passive motion postoperatively. Preoperative active extension for Group I was an average of 48° short of full extension, which improved to 19° at a mean follow-up time of forty-five months. Subsequently, eighteen patients (Group II) received continuous passive motion postoperatively for a mean of six weeks. Preoperative active extension for Group II was on average 55° short of full extension, which improved to 23° at a mean duration of follow-up of thirty-five months. The mean preoperative arc of motion for Group I was 69°, which improved to 94° postoperatively. The mean preoperative arc of motion for Group II was 48°, which improved to 95° postoperatively. Five patients in Group I and six patients in Group II had severe preoperative heterotopic ossification. There was no correlation, however, between preoperative heterotopic ossification and the amount that extension of the elbow improved postoperatively. There was no postoperative increase in heterotopic ossification (Figure 4).

The primary finding is the use of CPM on average for six weeks post-operatively improved the total arc of motion following an anterior capsulotomy by 47^{0} compared to 25^{0} for the non-CPM group. The difference between the groups was statistically significant.

9. Olivier LC, Assenmacher S, Setareh E, Schmit-Neverburg KP: Grading of functional results of elbow joint artholysis after fracture treatment. *Arch Orthop Trauma Surg.* **120:562-569, 2000.**

In the treatment of post-traumatic contracture of the elbow joint, arthrolysis is a proven procedure. A stepwise operative approach was used starting laterally and including an additional medial and dorsal incision if needed. A total of 91 patients with arthrolysis of the elbow could be followed-up on average of 44 months (range 9-102 months) after operative (58, 63.7%) and non-operative (33, 36.3%) fracture treatment. The mean preoperative range of motion (ROM) in flexion/extension was 49° (SD ± 38°), while in pronation/supination it was 89° (SD ± 66°). Postoperatively, the ROM was on average 94° (SD ± 27°) in flexion/extension and 129° (SD ± 52°) in pronation/supination. Using our own grading system, it became evident that most patients had a functional benefit from the procedure, although the quality of the improvement differed. For example, postoperatively 59.3% of the patients were grade I (90°) in flexion/extension compared with 16.5% preoperatively (Figure 5).

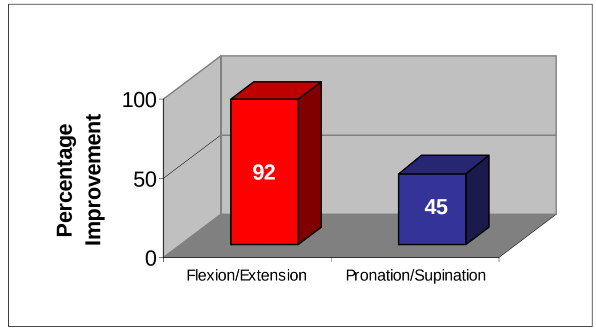

Figure 5
CPM was statistically significant following the surgical release of a joint ($p < 0.05$).

The earlier the release of the joints was performed; the better was the functional outcome ($p < 0.05$). The importance of an intensive early continuous passive motion program is emphasized.

10. Wu CC: Posttraumatic contracture of the elbow treated with intraarticular techniques: *Arch Ortho Trauma Surg* **123(9): 494-500, 2003.**

Posttraumatic contracture of the elbow is very disabling. However, an absolutely convincing surgical technique has not been defined in the literature. We developed an intraarticular technique to concomitantly treat both intraarticular and extra-articular lesions with one posterior incision. Twenty consecutive adult patients were treated with anteroposterior capsule release. Immediately postoperatively, continuous passive motion was initiated. All 20 patients were followed up for median of 3.8 (range 2.1-2.2) years. The satisfactory rate was 95% (19 of 20, $p<0.001$). The flexion contracture improved from an average of 42^0 to 13^0 which was statistically significant ($p<0.001$), and maximal flexion improved from an average of 89^0 to 131^0 ($p<0.001$). The arc of motion improved from an average of 47^0 to 118^0 ($p<0.001$). The sole unsatisfactory patient still had 20**°**-110**°** arc of motion. There were no evident complications noted (Figure 6).

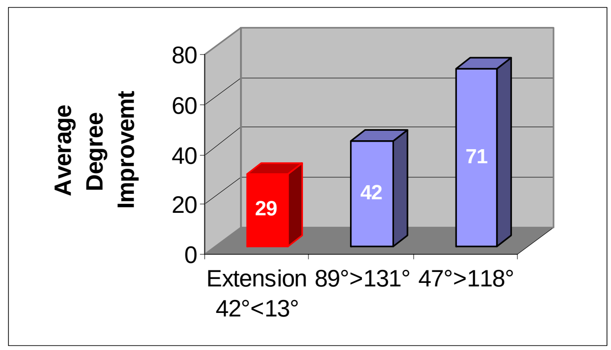

Figure 6
Statistically significant improvements where researched due in part to the use of CPM post fracture.

The primary finding is the surgical technique resulted in a high satisfaction rate, low complication rate and a statistically significant improvement in ROM with the use of CPM postoperatively.

11. Bae DS, Waters P: Surgical treatment of posttraumatic elbow contracture in adolescents: *J Ped Ortho* **21(5): 580-584, 2001.**

Thirteen adolescent patients with posttraumatic elbow contractures were treated with open surgical release at an average of 16.2 years of age. When possible, an extensile medial approach to the elbow was used. All patients were treated with 6 weeks of postoperative continuous passive motion. Eleven patients with >6 months of follow-up were evaluated at an average of 29 months after surgery. Average loss of extension improved from 57° to 15°, and average flexion improved from 109° to 123°. Average total arc of motion improved from 53° to 107° (Figure 7).

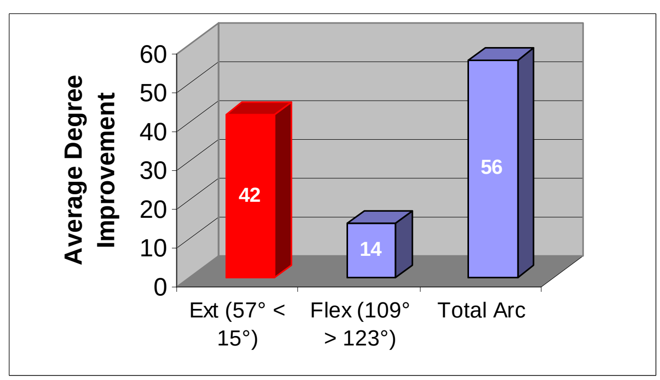

Figure 7
The CPM grouped reached the functional ROM level of 100° more often compared to the non-CPM group which did not reach the functional ROM level as often.

The primary finding by the author is functional ROM was reached (great then a 100^0 arc) on average with the use of CPM postoperatively for 6 weeks.

12. Phillips B, Strasburger S: Arthroscopic treatment of arthrofibrosis of the elbow joint. *J Arthro Rel Surg* **14(1), 1998.**

Twenty-five patients with arthrofibrosis of the elbow were treated with arthroscopic debridement followed by post-operative use of CPM; 15 had post-traumatic arthrofibrosis and 10 had contractures caused by degenerative arthritis. At an average follow-up of 18 months, all patients had increased motion and decreased pain. One patient required re-operation because of continued stiffness and pain; she had moderate pain before surgery, mild pain after initial debridement, and occasional mild pain after the second operation. Patients with post-traumatic arthritis had more severe flexion contractures preoperatively than did those with degenerative arthritis, but they also had more improvement postoperatively (Figure 8).

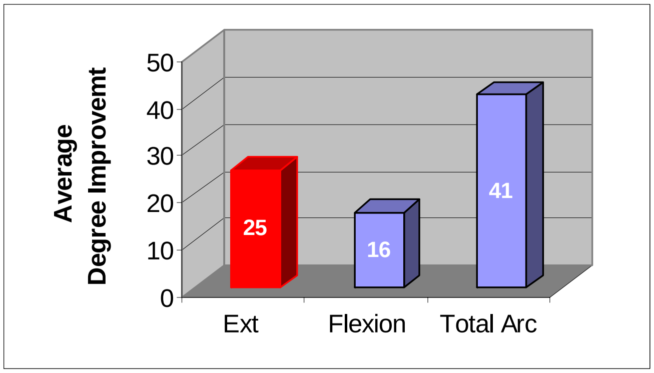

Figure 8
ROM improvements were statistically superior to protocols that did not use CPM post-operatively.

The primary finding of this study is arthroscopic release and debridement of arthrofibrotic elbow joints followed by the use of CPM obtained improvements equal to that obtained by open techniques, with less morbidity and earlier rehabilitation. Range-of-motion improvements were statistically significant (P=0.001).

13. Breitfus H, Muhrg G, Neuman K, Rehn; Arthrolysis of post-traumatic stiff elbow: Which factors influence the end result. *Unfallchirurg* **94(1):33-9, 1991.**

The results obtained with elbow arthrolysis performed for the treatment of posttraumatic stiffness were analyzed via a retrospective study of 59 patients. The intra-operative functional result was classified as excellent in all cases, while on average 27 months after the operation the range of movement was decreased again to varying extents. This deficit correlated with the type of injury, timing of arthrolysis, duration of metal implants and timing and type of postoperative rehabilitation program. The relative increase in function was better after simple fractures, with 47%, than after fracture dislocations, with 35%. After arthrolysis within 3 months of onset of posttraumatic stiffness the range of improvement was 55%, compared with an increase of only 30% after 10 months' stiffness. When arthrolysis was combined with metal removal and the implants had been in place for longer than 9 months the increase achieved was only 15%. Patients started on CPM on the 1st day postoperatively lost only 15% of their intra-operative function. If CPM was delayed to between the 2nd and 5th day, 30% was lost. Utilizing a splint program for maximal joint flexion and extension at 4-hour intervals instead of CPM resulted in a 35% loss of range of movement postoperatively. In contrast there was a loss of only 17% in the group with combined physiotherapy and continuous passive motion (Figure 9).

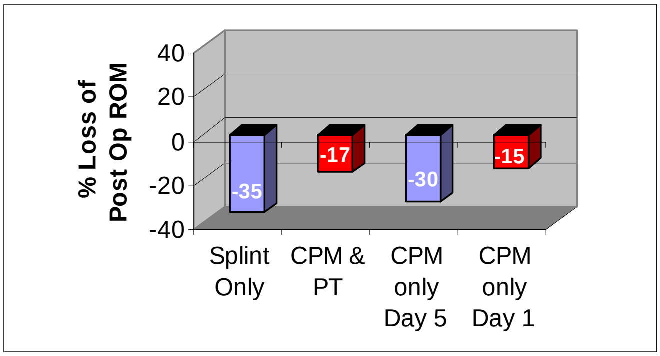

Figure 9
Statistically superior results were obtained when CPM was applied with in 48 hours compared to a delayed application. Even delayed CPM use was superior to non-CPM protocols.

The results show that the prognosis of elbow arthrolysis is determined by early mobilization with a CPM device and optimal operative planning. The time to arthrolysis should be as short as possible, as should the time to removal of metal implants. The aim of the rehabilitation program is immediate postoperative continuous passive motion.

14. Schindler A, Yaffe B, Chetrit A, Modan M, Engel J: Factors influencing elbow arthrolysis. *Ann Chir Maine Super* **10(3): 237-42, 1991.**

Over the period 1982 to 1988, 31 consecutive patients at the Hand Surgery Unit of the Sheba Medical Centre were subjected to elbow joint arthrolysis to treat restriction of range of motion solely due to trauma. This retrospective study aims to evaluate the relative influence of the following factors on functional outcome: sex, age, type of original injury and initial management, presences of para-articular ossification, delay between injury and arthrolysis, and the use of manipulation and a continuous passive motion device (CPM) following surgery. The range of motion was recorded prior to arthrolysis and after operation (excluding one patient who subsequently underwent arthrodesis for intractable pain). Follow-up averaged 15.3 months (±5.4). In the 24 patients with extension deficit (>20°), the mean improvement was of 26.9° (>23.1°); in the 21 patients with flexion deficit the mean improvement was 21.2° (>18°). The mean improvement for total range of motion in the series overall was 35.2° (±23.8°). 90% showed an improvement of at least 10° and 30% attained normal ROM. All of these improvements in range were highly statistically significant (figure 10) (p<0.0001) (Figure 10).

With regard to improvement in extension, the only variable of value was the use of a continuous passive motion device following surgery; those patients subjected to CPM showed a mean improvement of 32.6° (±19.0°), while those without averaged 12.8° (± 27.5°) (p<0.01). Respective rates of improvement beyond 10° were 88.2% vs. 28.6%, while the respective incidences of patient attaining normal extension were 64.7% vs. 14.3% (p=0.03) (Figure 11).

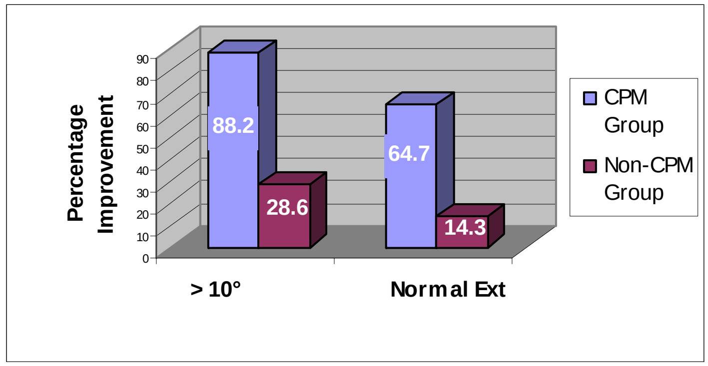

Figure 10
The CPM group reached functional ROM more often than the non-CPM group and the difference was statistically significant at (p< 0.001).

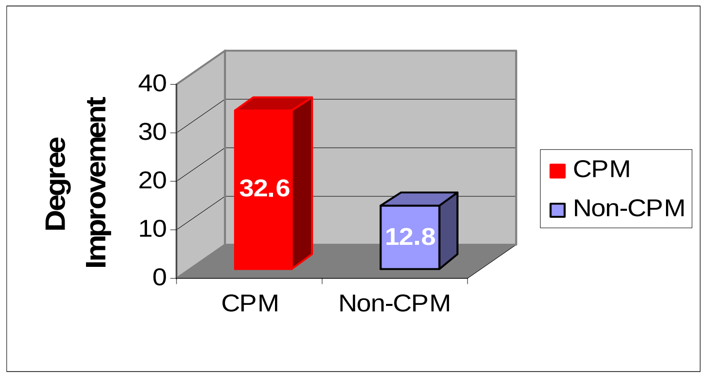

Figure 11
The CPM device was the only variable that demonstrated a statistically significant improvement in ROM.

15. Tsionos, I, Leclercq C, Rochet JM: Heterotopic ossification of the elbow in patients with burns: Results after early excision. *J Bone Joint Surg Br* **86-B:396-403, 2004.**

Heterotopic ossification which may develop around the elbow in patients with burns may lead to severe functional impairment. We describe the outcome of early excision for heterotopic ossification undertaken as soon as the patient's general and local condition allowed. The mean age at operation was 42 years. The mean area of burn surface burns was 40%. The mean pre-operative range-of-motion (ROM) was 22^0 in flexion/extension and 94^0 in pronation/supination. The mean time between burn and surgical release was 12 months with a median of 9.5 months. The mean follow up period was 21 months.

Between 1992 and 2001, a consecutive series of 28 patients with 35 elbow burns underwent a surgical release due to heterotopic ossification. All procedures were performed by the same surgeon followed by continuous passive motion (CPM) starting on the second postoperative day. The CPM was used for eight hours a day for three to four weeks with diminished daily use for another two to four weeks for a total of five to eight weeks. The CPM device was used as needed to gain ROM or to preserve ROM gained from the surgical release.

The gains in ROM were statistically significant improving from a mean of 22^0 to 123^0 in flexion/extension and a mean of 94^0 to 160^0 in pronation/supination. The improvement in ROM reached 100^0 in the total flexion/extension arc and 100^0 in the pronation/supination arc which is considered the minimum to perform most daily activities. The authors conclude that early

excision of elbows with heterotopic ossification following a severe burn followed by CPM is recommended to reach functional ROM.

SHOULDER

16. Bradley JP: Arthroscopic treatment for adhesive capsulitis. *Operative Techniques in Orthopaedics* **1(3), 248-252, 1991.**

This initial report describes the use of arthroscopy and subsequent manipulation followed by the postoperative use of continuous passive motion with fifteen patients who have primary adhesive capsulitis. CPM is initiated in the recovery room and is increased at home as comfort permits with use of at least ten hours per day. This preliminary study demonstrated the safety with positive results for CPM following manipulation under anesthesia for adhesive capsulitis.

17. Matsen Fa: Open release for posttraumatic stiff shoulder. *Video Journal of Orthopedics* **7012: August, 1991.**

Operative release is considered when motion is limited because of conditions such as motion interface adhesions or contracture of the subscapularis. Dr. Matsen reviews the principles and procedures common to every shoulder release surgery, specifically, the mobilization of the motion interface, coronal plane Z-plasty lengthening of the subscapularis, and 360-degree release of the subscapularis. In addition, he discusses his postoperative management. Dr. Matsen is professor of orthopaedics at the University of Washington School of Medicine and chief of the orthopaedic service at the University of Washington Hospital, both in Seattle. He is currently a member of the VJO editorial board and formerly served as president of the Shoulder and Elbow Society.

"Continuous passive motion is begun in most patients directly after the operation. The purpose is to retard or discourage adhesion development. During the surgery, a brachial plexus block technique is used that provides 12 to 18 hours of postoperative analgesia. This enables patients to learn directly after the operation, while pain is reduced, that range of motion is restored. As a result, most become dedicated to self-rehabilitation."

18. Bennet WF: Addressing glenohumeral stiffness while treating the painful and stiff shoulder arthroscopically. *The Journal of Arthroscopic and Related Surgery* **16(2), March, 2000.**

The shoulder can be primarily or secondarily stiff. Cadaver studies have shown increases in passive range of glenohumeral motion when certain portions of the capsule are released. This study has recorded the intraoperative gains made in passive range of motion for external rotation, flexion, abduction, and internal rotation with sequential release of the rotator interval, inferior capsule, and posterosuperior capsule, regardless of initial etiology and follow-up over time. A shoulder CPM device was a primary tool for passive range of motion therapy. Thirty one of 60 shoulders, found clinically to have a loss of passive range of motion and having failed a nonoperative approach, underwent a capsular release. Eighteen patients underwent a partial capsular release (group 1) and 13 patients (group 2) underwent a complete capsular release. Thirty of 31 shoulders had statistically significant gains in passive range of motion with sequential release. In general, resection of the rotator interval contributed to gains in external rotation; resection of the inferior capsule (anteroinferior and posteroinferior) contributed gains to external rotation, forward flexion, and internal rotation; and resection of the posterosuperior capsule contributed to gains only in internal rotation. At a minimum of 18 months follow-up, 30 of 31 shoulders retained their intraoperative gains ($P > .05$).
The primary finding is that an arthroscopic release of capsular tightness is beneficial in returning shoulders with a loss of passive glenohumeral motion to normal regardless of the etiology. A secondary finding is that CPM use was a primary factor in the results achieved.

19. Nicholson GP: Arthroscopic Capsular release for stiff shoulders effect of etiology on outcomes. *The Journal of Arthroscopy and Related Surgery* **19(1): January, 2003.**

The etiology, pathogenesis, time course, and response to treatment of stiff shoulder pathology are still under investigation and debate. This prospective study evaluated arthroscopic capsular release to treat stiff shoulder pathology that was resistant to conservative management. The etiology of the shoulder stiffness was categorized and analyzed for effect on outcomes.

In 68 stiff shoulders (41 women, 27 men) that underwent arthroscopic capsular release, 5 distinct etiologies were identified: postsurgical in 20, idiopathic in 17, post-traumatic in 15, diabetic in 8, and impingement syndrome (prior primary impingement developing stiffness) in

8. Average age was 50 years (range, 29-72), and follow-up averaged 3 years (range, 2 to 8). Prior to this procedure, duration of symptoms averaged 7.3 months (range, 3 to 48), and formal physical therapy averaged 3.7 months (range, 1 to 12). Preoperative average American Shoulder and Elbow Surgeons Score (ASES) was 35.5 (range, 10 to 77), medial Simple Shoulder Test (SST) was 3 (0 to 10), and median Visual Analog Score (VAS) for pain was 6 (0 to 10). Average active forward elevation (FE) was 92°, external rotation (ER) at side was 12°, and medialinternal rotation (IR) was to the buttock (Figure 12). All patients underwent arthroscopic capsular release with continuous passive motion postoperatively.

The study population showed significant improvement (p<.0001) for all outcome scores and active motion parameters. Average and median outcome parameters for the population, with improvement in parenthesis were: ASES 93 (+57.5), SST 10 (+7), VAS 0 (-6), FE 165° (+73°), ER at side 56° (+44°), and IR to T -12 (+7 spinal segments). The time in formal physical therapy averaged 2.3 months (2 to 20 weeks) and time to attain final, pain-free range of motion averaged 2.8 months (1 to 6). Outcomes for, and between, each etiology were analyzed.

Stiff shoulder pathology can result from a variety of differing etiologic factors. Arthroscopic capsular release with postoperative CPM was equally effective across the 5 identified etiologic groups, and provided significant pain relief, restoration of motion, and function within an average of 3 months.

SUMMARY/DISCUSSION

Prior to 1989 there were few reports on the use of CPM following the surgical release of a joint contracture or the use of CPM post-trauma. Frykman[35] reported statistically superior outcomes (p<.05) on the use of CPM for stiff MP and PIP joints of the hand for posttraumatic ankylosis in 1989. CPM for six weeks in duration was tried after a vigorous hand therapy program had failed or after a previous surgical intervention without CPM had failed. Bradley[12] reported significant positive results with CPM use for 10 hours per day after arthroscopy and manipulation for primary adhesive capsulitis of the shoulder in 1991. Also in 1991, a retrospective study by Breitfus[13] found CPM to be superior to physical therapy and a splinting program. The author also looked at start time and found superior results were seen when CPM was started within 48 hours following the surgical procedure. A second retrospective study was done by Schindler[126] between1982-1988 and found CPM the only rehabilitation variable of value. CPM was initiated following an arthrolysis procedure for a contracted joint and resulted in a statistically significant improvement (p<0.01) both in range of motion and function (88% of CPM users improved more then 10^0 while only 29% of non users had similar success).

A study by Gates[41] in 1992 compared physical therapy to a CPM (six weeks) protocol following a release of a joint contracture. The CPM group improved a mean of 47˚ compared to only 25˚ in the physical therapy group. Ippolito[52] also reported functional improvements with CPM after six weeks of use compared to a similar series who only utilized physical therapy in 1999. The importance of an intensive early CPM program was emphasized by both Olivier[99] and Bennet[10] following surgical releases in 2000. Olivier[99] had ninety-one patients and Bennet[10] had sixty-eight patients who reached statistically significant (p<0.05) gains in range of motion and function after a capsulotomy and post op use of CPM. Aldridge[4] compared the efficacy of CPM to a traditional splinting program in 2004. Splinting programs following a surgical release of a stiff joint had been the standard of practice with many surgeons. This study of 106 joints joins the growing body of research demonstrating statistically superior results with CPM (p=0.27) over splint and physical therapy only programs.

Nicholson[85] found that CPM following an arthroscopic release was equally effective across five identified etiologic groups as well as providing pain relief in 2003. Recent studies by Bae & Waters[8] in 2001, Tsionos[135] in 2004, and Wu[143] in 2003 confirm that CPM following a joint release to the shoulder, elbow or hand is needed to reach functional range of motion.

The average period of use was six weeks following a surgical release or manipulation of the shoulder, elbow or hand in order to reach statistically significant improvements in range of motion and function. Only one author out of sixteen authors mentioned that they used CPM for only 4 weeks. Actual duration depended on the patient. If the patients range of motion stabilized (no increase or decrease) then CPM was reduced or discontinued. If a loss of motion was detected or continued gains seen then CPM was continued.

Clinical Guidelines for Surgical Release, Manipulation Under Anesthesia, Contracture/Stiffness[4,8,10,12,13,35,41,52,60,85,99,100,126,135,143]

1. SET-UP

- The patient is fitted and instructed on use of the Kinex Hand CPM Device (preoperatively if possible to improve compliance).[60,128]
  - **Repeatable Anatomical Position**: Kinex CPM is aligned to the patient to ensure correct positioning each time the CPM device is used.
- CPM use is initiated 24-48 hours postoperatively, if possible.[5,13,35,60,85,143]
- The Kinex Hand CPM Device is positioned in maximum flexion and extension for the involved joints.

2. WEARING SCHEDULE GUIDELINE

- The Kinex CPM Device is used for 6-8 weeks or as needed.[8,34,41,60,135]
- Week one: CPM is used 6-20 hours per day or as needed.[58]
- Week two and beyond: the CPM is used for 4-8 hours per day in 3-4 sessions or as directed.[60,128]
  - **Kinex Static-Progressive-Stretch Mode:** This mode is used to gain motion do to joint or soft tissue stiffness and is utilized if gains from standard continuous passive motion have plateaued . The Kinex CPM device is placed at end-range with the pause mode set at 5 minutes. After 5 minutes the CPM device is increased to the new end-range. This continues 1-2X a day for 30-60 minutes, week one. Week two the duration is increased to 2-3X a day. Week 3 and beyond the sessions are 60-90 minutes 3X a day.

3. PROM GOALS

- The patient increases ROM as tolerated to meet ROM goals.[53,60,128]
- CPM use should continue if PROM goals have not been met.[60]
- Kinex CPM device can be set at a static-progressive-stretch mode if patient is not progressing as expected.
- Full joint motion may be less during the first 2-3 weeks postoperatively due to swelling.[60]
- Note: This device must be used under the advice and care of a physician.

Peer-Reviewed Studies Evaluating Outcome Measures for the Efficacy of CPM Following the Surgical Release or Post Trauma Stiffness

Clinical Study	Purpose of Study	Duration of Use	Results	Primary Finding
CPM Improves Range of Motion after PIP and MP Capsulectomies; A Controlled Prospective Study: Frykman et al (1989, American Society for the Surgery of the Hand, 44th annual meeting)	A controlled prospective study that evaluated the use of CPM after capsulectomy of the MP and PIP joints for posttraumatic ankylosis. All had failed to improve from a vigorus hand therapy program and several had failed a previous capsulectomy procedure w	CPM was used on average for 6 weeks after surgery.	Both groups received the same postoperative hand therapy program with CPM the only difference between groups. The CPM group had statistically superior gains in ROM (p<.05) over the non-CPM group with less pain.	The CPM group following a MP or PIP capsulectomy had a statistically significant (p<.05) gain in PROM & AROM in contrast to the conventional hand therapy program only.
Anterior Release of the Elbow for Extension Loss:Aldridge et al (2004, J Bone Jt Surg)	Compared the efficacy of CPM to splinting only following the surgical release of 106 elbow joints	CPM was used 4 weeks or longer depending on the severity of the contracture.	The total arc of motion increased 45º in the CPM group & only 26º in the splinting only group. This difference is statistically significant, p=0.27.	CPM following a surgical release offers a statistically superior (p=0.27) functional outcome over splinting alone & physical therapy.
Resection of Elbow Ossification and Continuous Passive Motion in Postcomatose Patients:Ippolito et al (1999, J Hand Surg)	Heterotopic periarticular ossifications were surgically excised in 16 elbow joints of traumatic brain injury patients.	The CPM was used for 6 weeks before starting a fully active rehabilitation program.	ROM improvements were greater then five previous investigators with a similar series of patients with out CPM.	CPM is more effective in reaching functional range of motion after 6 weeks then physical therapy alone following a surgical release.
Anterior Capsulotomy and Continuous Passive Motion in the Treatment of Posttraumatic Flexion Contracture of the Elbow; A Prospective Study: Gates et al (1992, J Bone Jt Surg)	Thirty-three patients who had a post-truamatic flexion contracture of the elbow under went an anterior capsulotomy. Fifteen patients did not receive CPM & eighteen patients did receive CPM postoperatively.	CPM was used for a mean of 6 weeks.	The mean postoperative arc of motion improved 25º in the physical therapy group and 47º in the CPM group. The difference was statistically significant.	CPM following the release of a flexion contracture resulted in a statistically significant improvement in function compared to the non-CPM group.
Grading of Functional Results of Elbow Joint Arthrolysis after Fracture Treatment: Olivier et al (2000, Arch Orthop Trauma Surg.)	Ninety-one patients were treated with arthrolysis for a posttraumatic contracture followed by the use of CPM.	Not Reported	The mean ROM improved from 49º to 94º in flexion and 89º to 129º in pronation/supination. The results were statistically significant at p<0.05.	The importance of an intensive early CPM program is emphasized as the results were statistically significant.
Posttraumatic Contracture of the Elbow Treated with Intraarticular Techniques: Wu (2003, Arch Ortho Trauma Surg)	Twenty consecutive adult patients underwent a anteroposterior capsule release. Immediately postoperatively, CPM was initiated.	Not Reported	The flexion contracture improved from a mean of 42º to 13º, flexion improved from 89º to 131º, & the total arc improved from 47º to 118º. All improvements were statistically significant at p<0.001.	A statistically significant improvement (p<0.001) in functional ROM was seen do to the use of CPM post release.
Surgical Treatment of Posttraumatic Elbow Contracture in Adolescents: Bae & Waters (2001, J Ped Ortho)	Thirteen adolescents with posttraumatic elbow contractures were treated with open surgical release followed by CPM.	CPM was used for 6 weeks postoperatively	Avg. loss of extension improved from 57º to 15º, avg. flexion improved from 109º to 123º & total arc improved from 53º to 107º.	Open surgical release followed by the use of CPM for 6 weeks resulted in a significant improvement in functional ROM (>100º) in adolescents.
Arthroscopic Treatment of Arthrofibrosis of the Elbow Joint: Phillips & Strasburger (1998, J Arthro Rel Surg)	Twenty-five patients with arthrofibrosis were treated with arthroscopic debridement and CPM postoperatively.	Not Reported	At an average follow up of 18 months all patients had a statistically significant (p=0.001) increase in ROM and decreased pain.	Arthroscopic release followed by CPM use obtained improvements equal to open techniques with CPM use.
Arthrolysis of Posttraumatic Stiff Elbow;Which Factors Influence the End Result: Breitfus et al (1991, Unfallchivrg)	A retrospective study of 59 patients who received an arthrolysis for psottraumatic stiffnes. CPM was compared to spinting and physical therapy. CPM start times were also evaluated.	Not Reported	Patients started on CPM day one lost 15% of intraoperative function while those delayed to day five lost 30%. The combined PT and CPM group lost 17% compared to the splinting group which lost 35%. The CPM gains were statistically significant.	Statistically superior results were obtianed with CPM compared to a splinting program. CPM started with in 48 hours did better then when CPM was started day 5. Even delayed CPM use was superior to non-CPM protocols.
Factors Influencing Elbow Arthrolysis: Schindler et al(1991, Ann Chir Maine Super)	Retrospective study between 1982 & 1988 which evaluated the use of CPM following an arthrolysis procedure.	Not Reported	All of the improvements were statistically signifcant, p<0.0001. 88.2% of CPM users improved beyond 10º vs. only 28.6% for non-CPM users, while 64.7% of patients in the CPM group reached normal extension only 14.3% did in the non-CPM group (p=0.03).	The only variable of value was the use of CPM following surgery. The CPM mean improvement (32.60) was statistically superior then the non-CPM group (12.80), p<0.01.
Heterotopic Ossification of the Elbow in Patients with Burns: Results after early Excision: Tsionos et al (2004, J Bone Jt Surg Br)	Between 1992 & 2001, 35 elbows underwent a surgical release due to heterotopic ossification. CPM began on the 2nd postoperative day.	CPM was used for 5-8 weeks.	The gains were statistically significant from a mean of 22º to 123º in flexion/extension & 94º to 160º in pronation/supination.	A 100º arc is considered to be functional. The authors conclude that CPM is needed following a release to reach functional ROM.
Arthroscopic Treament for Adhesive Capsulitis. Bradley (1991, Operative Techniques in Orthopaedics)	The initial report describes the use of CPM following arthroscopy and manipulation for primary adhesive capsulitis of the shoulder.	Not Reported	CPM is used 10 hours per day with positive results.	This preliminary study demonstrated the safety of shoulder CPM with positive results following manipulation under anesthesia for adhesive capsulitis.
Addressing Glenohumeral Stiffness while Treating the Painful and Stiff Shoulder Arthroscopically: Bennet (2000. J Arthrosc Rel Surg)	Thirty-one patients received either a partial or complete capsular release of the shoulder followed by CPM for passive motion therapy.	Not Reported	Thirty of thrity-one patients had a statistically significant increase in ROM (p>.05).	CPM use was a primary factor in the statistically significant results achieved.
Arthroscopic Capsular Release for Stiff Shoulders Effect of Etiology on Outcomes: Nicholson (2003, J Arthrosc Rel Surg)	Prospective study evaluated outcomes in 68 stiff shoulders following arthroscopic capsular release followed by the use of CPM postoperatively.	Not Reported	The study population showed a significant improvement, p<0.001. Mean improvement in ASES score was 35.5 to 93. Flexion improved from 92º to 165º & Ext. Rot. Improved from 12º to 56º.	Arthroscopic shoulder capsular release with postoperative CPM was equally effectve across 5 identified etiologic groups and provided pain relief, restoration of motion and funciton within an average of 3 months.

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