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Restoring range of motion via stress relaxation and static progressive stretch in posttraumatic elbow contractures

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Hypothesis: Loss of range of motion after injury or surgery of the elbow is a common complication. We hypothesized that an orthosis that used progressive stretch and stress relaxation principles would improve elbow range of motion.

Methods: This study evaluated the result of a patient-directed, bidirectional orthosis that uses static progressive stretch and stress relaxation principles to improve elbow range of motion in patients who had posttraumatic elbow contractures. Treatment in 37 elbows consisted of a 30-minute stretching protocol performed in 1 to 3 sessions daily for a mean of 10 weeks (range, 2-22 weeks).

Results: The mean gain in range of motion was 26° (range, 2°-60°). Gains of motion were noted in 35 of 37 elbows. Patients lowered their analgesic use and were highly satisfied with the device (mean satisfaction score of 8.5 of 10 points possible).

Discussion: This device compared favorably with reports of other devices. Consistent improvements in restoring range of motion can be achieved with short treatment times by using a device based on the principles of static progressive stretch and stress relaxation in patients with posttraumatic elbow contractures.

Level of evidence: Level 4; Case series.

Keywords: Orthosis; static progressive stretch; stress relaxation; elbow range of motion

Elbow joint stiffness and loss of motion develops in many patients secondary to complications of disease, injury, or trauma after surgery. Restoring range of motion (ROM), function, and independence remains a challenge in posttraumatic patients, and the focus has shifted to involving the patient more directly in the rehabilitation program.[9] Splints have been suggested as useful tools to improve motion when standard exercises alone seem insufficient.

Connective tissue is capable of being stretched after it shortens because of its viscoelastic nature. Under tension, it can respond by reaching either an elastic or plastic deformation state. In elastic deformation, tissue reverts to its original length after a force is removed; however, when

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tissue is plastically deformed, it will maintain a newly elongated length after removal of the force. Mechanical devices have been used as part of a stretching treatment program to assist in achieving the lengthened plastically deformed state. Stretching leads to tissue remodeling; this leads to increased length without requiring new growth.[15]

When mechanical devices are used, 2 types of loading conditions have been applied to obtain plastic deformation of soft tissue: creep-based and stress relaxation.[1] In creep-based loading, a constant force is applied over time while displacement varies. Historically, ROM limitations have been treated in the home setting using dynamic splinting devices with low load, prolonged stretch, and creep-based loading. Devices that are based on these principles must be worn for as many as 12 hours daily for up to 7.5 months.[7,8,12] Success rates vary because the tissue may not reach the plastic deformation state, and the patient can lose ROM after removing the device.[7,8,12] The prolonged wearing time does not promote patient compliance and can lead to skin irritation and breakdown. Few peer reviewed studies have described the efficacy of dynamic tension splinting that address such issues as tissue response, wear time, or cost.[5,10,14]

With stress relaxation loading, the displacement is constant, and the applied force varies over time. Applying a stress relaxation loading condition to a material with viscoelastic properties will cause the material to reach the plastic deformation state more quickly than applying a creep-based loading.[1,3] Turnbuckle splinting also uses stress relaxation. Stress relaxation principles can be further applied in the therapeutic technique of static progressive stretch. Static progressive stretch is defined as incremental, periodic application of stress relaxation where the force applied changes over time as the tissue accommodates.[3]

This study assessed the use of an orthosis that uses the principles of stress relaxation and static progressive stretch to primarily understand whether it could improve ROM in posttraumatic elbow contracture patients who had plateaued with physical therapy. Secondary questions included the effectiveness of this device by an analysis of analgesic use and satisfaction.

Materials and methods

The study was approved by the Institutional Review/Ethics Committee of St. Anthony's Memorial Hospital, Effingham, Illinois.

This study is a clinical retrospective review of 37 consecutive patients with loss of motion of the elbow joint after posttraumatic elbow injuries who were treated from January 1, 2002, to December 31, 2005. A patient-directed, bidirectional orthosis was used in the home setting. Inclusion criteria for the study were:

1. adult patient (age, 18 years or older);
2. elbow trauma;
3. minimum of 6 weeks of exercises, with or without physical therapist guidance;
4. loss of flexion/extension elbow functional ROM, defined as either a loss of full extension of 15° or more or flexion of less than 120°, or both; and
5. minimum of 2 weeks of minimal motion gains (less than 5°) as well as a hard end point to motion as judged by the physical therapist.

The study excluded patients with atraumatic flexion contractures and those with elbows that had any degree of heterotopic ossification or true bony blocks to motion.

The 15 men and 22 women in the study were a mean age of 45 years (range, 22-78 years). Standard physical therapy techniques used for a mean of 12 weeks (range, 7-22 weeks) had failed in all patients before use of the device. This standard physical therapy included joint mobilization with normal stretching and ROM treatment, ultrasound, cryotherapy, and electrical stimulation.

The mean time from injury to the start of treatment with the device was 14 weeks (range, 7-35 weeks). The reasons for the elbow contractures and the patient demographics are stratified in Table I. Before application of the device, 15 patients had undergone surgery and 22 patients were treated nonoperatively.

The orthosis used was the JAS Elbow device (Joint Active Systems, Effingham, IL), which incorporates the principles of stress relaxation and static progressive stretch (Figure 1). The device consists of 2 padded sleeves for the forearm and upper arm connected by a metal connector bar that applies a spring-loaded force. It is designed to flex up to 135°.

All patients received instructions on the application of the device and its protocol for use. After the orthosis was placed on the injured arm at the limit of motion, patients were directed to increase the stretch to tolerance by turning the knob on the device and holding that position for 5 minutes. After this, they increased the stretch to tolerance and held the new position for another 5 minutes. They were instructed to stretch to their tolerance, and not to "pain," and continue this incremental stretching for the entire 30-minute treatment session.[2]

In the first week of treatment, patients underwent 1 treatment session each day. During the second treatment week, patients were instructed to increase to 2 treatment sessions each day. For the third and all successive weeks, patients underwent 3 treatment sessions of 30 minutes daily. When not using the splint, the patients were allowed to perform activities as tolerated. In addition, no resting splint, static splint, or formal physical therapy was used. When flexion and extension were both required, we specified 30 minutes of stretch in one direction, and then after 15 to 30 minutes of rest, a stretch in the opposite direction was used. The patients were instructed to treat the larger deficit first.

Success rate was evaluated by gain in ROM of extension and flexion, patient satisfaction with treatment, and the use of anti-inflammatory and analgesic medications. A goniometer was used to measure ROM, lining up the axes of the humerus and forearm to measure maximum extension and flexion, which was measured by both physical therapists and the senior author (MA.M.). When a disagreement between ROM measures exceeded 5°, a third physical therapist remeasured the ROM. Patient satisfaction was evaluated at final follow-up by the senior author using the 11-point ordinal Likert scale,[11] which ranges from 0 to 10, with 0 being unsatisfied and 10 being completely satisfied. Analgesic use, including the use of anti-inflammatory drugs, was characterized

Table I Demographic data for the posttraumatic elbow fractures in JAS elbow group

Characteristics	No. or mean	% or range
Demographic data		
Patients, total	37	100
Sex		
Men	15	41
Women	22	59
Age, years	45	22-78
Body mass index, kg/m^2	24	19-32
Weight, pounds	188	120-230
Diagnosis, elbows	37	100
Fractures	29	78
Radial head fracture	12	32
Radius fracture	5	13
Humerus fracture	11	29
Olecranon	1	2
Nonfractures	8	22
Dislocation	4	11
Joint contracture	4	11

before the device was used, during the device application, and at final follow-up evaluation. The brace was stopped when the senior author and physical therapists, who evaluated the patients at least twice weekly, considered there was a plateau with ROM gains that held constant for a 2-week period.

Pretreatment values were compared with the mean and median follow-up flexion, extension, and total ROM (the sum of flexion and extension) values. We could not evaluate the independent variables of gender, age, length of time from injury to treatment, or type of injury to determine whether any of these factors affected the final improvement in ROM because of the small numbers of patients and the excellent ROM gains in all but 2 patients.

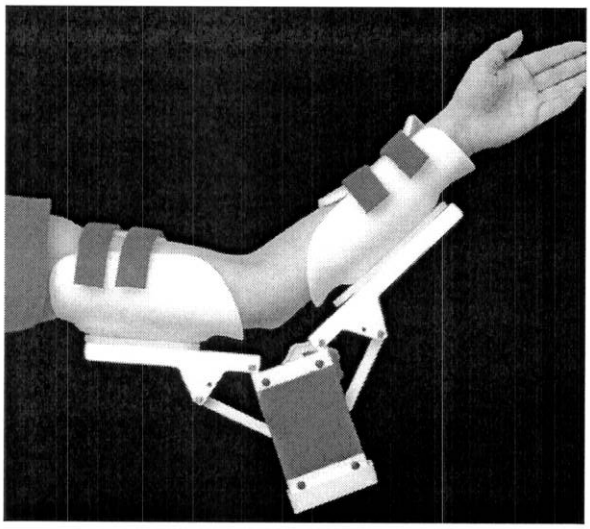

Figure 1 The JAS Elbow device (Joint Active Systems, Effingham, IL) incorporates the principles of stress relaxation and static progressive stretch. The device consists of 2 padded sleeves for the forearm and upper arm that are connected by a metal connector bar that applies a spring-loaded force. It is designed to flex up to 135°.

Results

All but 2 patients had an overall increase in ROM. The final overall, as well as the individual flexion and extension gains were statistically higher than the pretreatment values ($P < .001$). All patients completed the suggested treatment protocol at a mean treatment time of 10 weeks (range, 2-23 weeks).

The mean overall increase in ROM was 26° ± 14° (range, 2°-60°; median, 20°), considering both flexion and extension. Before use of the orthosis, the mean ROM was 8°1 ± 27° (range, 10°-120°; median, 82°), and after treatment, it increased to 107° ± 21° (range, 70°-140°; median, 110°). Patients gained an average of 10° ± 7° (range, 0°-33°; median, 10°) of additional extension and 16° ± 12.4° (range, 0°-50°; median, 14°) of additional flexion at a mean treatment time of 10 ± 5 weeks (range, 2-25 weeks; median, 8 weeks). Before the use of this device, the mean flexion was 110° ± 22° (range, 30°-140°; median, 110°) and the mean extension deficit was 30° ± 14° (range, 5°-55°; median, 28°). After the use of the device, the mean flexion improved to 125° ± 15° (range, 81°-145°; median, 130°) and mean extension deficit was 19 ± 12° (range, 0°-45°; median, 18°).

No patients required initiation of anti-inflammatory or narcotic medications during the treatment with the device. Before physical therapy treatment, 16 patients were taking long-term anti-inflammatory drugs and 3 patients were taking long-term narcotic medications. During the device treatment, no dosages of analgesic or anti-inflammatory medications had to be increased. After completion of their treatment, no additional patients required the use of analgesic medications, and only 7 patients were taking any analgesics.

Analysis of overall patient satisfaction scores showed that 35 of 37 patients (94%) had satisfaction index scores of 8 points or more at final follow-up, with a mean of 8.5 points (range, 0-10 points). Two patients reported a satisfaction index score of 2 points; both cited a bad surgical outcome as the primary reason for their dissatisfaction.

Shoulder problems developed in both patients who lost overall ROM, so their device treatment was discontinued, and treatment was subsequently focused on their shoulder problems. One of those patients lost 8° and the other lost 10° total elbow ROM. There were no skin or ulnar nerve problems, and no patients withdrew from the study.

Discussion

Treating patients with elbow flexion contractures can be difficult. Historically, manual therapy has been used as an initial treatment for increasing ROM in any contracted

joint. It can be time-consuming, with extensive treatment that requires the patient to visit therapists multiple times each week for many months. With the increased emphasis placed on patient outcomes and cost savings, various orthotic devices have been developed for home use. The goal of these devices should be the same as manual therapy: plastically deforming tissue using the principles of stress relaxation. Unfortunately, recommendations about the various devices can vary dramatically. Patients may sometimes need 6 months of treatment or longer. Often patients need to wear these devices for more than 8 to 12 hours each day. Because of the long treatment times and occasional low success rates, the current study was initiated using a device that incorporates the principles of static progressive stretch and relaxation to try to increase the efficacy of treating posttraumatic elbow contractures.

One limitation of the present study was that these patients were not concurrently compared with patients treated by other methods. However, because of the tremendous gains in motion in a short period of time with the present methods, we believe that this device compares favorably with other devices that have required many hours of daily treatment time and many months to achieve their effect. Another limitation was the small number of patients (n = 37) in the study, which precluded analysis of stratified variables. Unfortunately, most of the studies to date that have treated elbow contractures have included less than 30 patients.

A comparison with the literature revealed that the success rate of the device used in the present study compared favorably with other creep and stress relaxation devices (Table II). Most studies had ROM improvement success rates of 81% to 88%, with longer treatment times of 6 to 10 hours daily for 6 to 10 months.

The delay of initiation of orthosis use was a mean of 14 weeks. It is possible that some of these patients would have had further gains in motion without the use of the device, although they all had reached firm end points with no motion gains for the 2-week period before usage, which makes it likely that the device was efficacious in these patients. Some of the patients who were started on treatment at 6 weeks might possibly still have had further gains; however, the group that plateaued after 12 weeks of standard physical therapy still had excellent mean ROM gains. On the other hand, it might be expeditious to begin splinting earlier on. At this point, the ideal time to begin the protocol has yet to be defined, although we believe that treatment might be started much earlier. A prospective, randomized, controlled study comparing this device with others would be appropriate for study.

The most common and widespread protocol for posttraumatic or surgical joint stiffness is for patients to use a device as an adjunct to a therapy program while they are receiving supervised physiotherapy. The criteria for initiating splint use should presently be when patients are not achieving gains in ROM with standard therapy in the expected time frame and thus are at risk for prolonged and costly therapy, permanent contracture, or need for surgical intervention. It is important to note that a physiotherapy program may be addressing several other critical rehabilitation goals in addition to ROM restoration, including edema, pain, strengthening, and functional reeducation. Regaining ROM is a critical step that precedes the patient's ability to regain full functional strength and use of the limb. A stretch device should not simply replace a course of therapy for these patients.

In addition, patients in this study were instructed to stretch only to tolerance and not to pain, which might be counterproductive in regaining motion in contracture patients by reinforcing misconceptions about pain. Thus, the type of instructions given to these patients deserves further study.

To try to save time in treating elbow contractures without using labor-intensive manual techniques, various types of devices using stress relaxation principles have been used; however, many of these devices still need prolonged treatment. The turnbuckle splint is a double-upright long-arm orthosis with a turnbuckle on the outside upright that has been used for the elbow in 2 studies. Green et al[6] analyzed 15 patients who were treated with these splints for 20 hours daily and found an average improvement of ROM of 43°, with a success rate of 80%. Gelinas et al[5] treated 22 patients and described a success rate of 86% in improving ROM. These authors did not advocate using turnbuckle splints because of the low patient compliance, perhaps

Table II Comparison studies of upper extremity devices

First author	Year	Device	Mechanism	Patients, No.	Success rate, %	Time of treatment
Green	1979	Turnbuckle	SR	15	80	20 h/d up to 7 mon
Hepburn	1984	Dynamic splint	Creep	1	N/A	12 h/d up to 7.5 mon
Hepburn	1987	Dynamic splint	Creep	13	61	8-12 h/d up to 5 mon
MacKay-Lyons	1989	Dynamic splint	Creep	1	N/A	12 h/d up to 7.5 mon
Bonutti	1994	JAS	SPS	20	100	30 min/d
Gelinas	2000	Turnbuckle	SR	22	86	20 h/d
Doornberg	2006	JAS	SPS	29	88	3 × 1.5 h/d up to 4 mon
Present study	2007	JAS	SPS	52	96	30 min to 3.5 h/d up to 3 mon

Creep, creep-based; *N/A*, not applicable; *SPS*, static progressive stretch; *SR*, stress relaxation and manual therapy.

secondary to the long treatment times that were necessary to achieve successful results.

Doornberg et al[3] recently studied a device similar to the one used in our study that produced static progressive stretch for treating elbow contractures. In their 29 consecutive patients who had elbow stiffness after trauma, 14 were treated after an operation for their initial injury, and 12 were treated after secondary contracture release for posttraumatic stiffness. The device was used for a mean of 4 months (range, 1-9 months), and they had an 88% success rate at improving ROM at a mean of 11 months of final follow-up (range, 2-28 months). Three patients (10%) in the Doornberg et al study required further operative release of contractures.

Our results also compare favorably with various studies that have used principles of creep to achieve their effect. For example, Hepburn[8] studied patients with elbow contractures with a device that required 12 hours of treatment daily for 7.5 months, and the success rate at improving ROM was only 60%. In another study by Steffen and Mollinger,[13] patients were required to wear splints every night for 6 months to treat knee flexion contractures. At final follow-up of 6 months, the 28 patients had a ROM increase success rate of only 58% with a treatment time of 3 hours each day, 5 days each week. It appears that devices that use creep principles, such as dynamic splints, can be effective but may require prolonged treatment times.

A previous study of static progressive stretch using the device in the present study analyzed 20 patients with elbow contractures.[2] Patients used the device in 30-minute treatment protocols, and the time of treatment varied between 1 and 3 months. The authors found a mean increase in ROM of 31° (69% increase) during a 1- to 3-month treatment and an overall success rate of 100% at final follow-up,[2] which compares similarly to the results the present study.

Various splints for elbow contracture have recently addressed the implication of ulnar nerve symptoms and final outcome.[1,11] In the present series, the ulnar nerve did not appear to be an issue in the treatment of these patients. Since completion of this study, we have treated 3 patients who presented with ulnar nerve symptoms when the protocol was used for 30-minute sessions. In these situations, we have shortened the treatment protocol to 15 minutes, or to as little as 10 minutes. Two or three 10-minute sessions are used rather than one 30-minute session. This eliminated the ulnar nerve symptoms and remained effective.

Costs and economics using stress relaxation devices were studied by Doornberg et al.[4] They showed a significant financial effect in cost when a brace was used for the treatment of posttraumatic elbow stiffness. They concluded that use of an elbow device for patients who did not respond to standard therapy prevented the need for operative release in more than 75% of the individuals. In the present study, the use a device for 6 weeks with 3 supervised visits was $673 compared with $1320 for standard physical therapy, assuming three 30-minute sessions each week (see Appendix). We believe that the use of these devices for elbow contractures can lower the cost of treatment.

Conclusions

The present study showed that 35 of 37 patients had a mean overall increase in elbow ROM of approximately 26° using an orthotic device for a mean of 10 weeks. Patients had high satisfaction and decreased their analgesic usage. The results demonstrate that this orthosis, which uses the principles of static progressive stretch and stress relaxation, can increase ROM effectively.

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Disclaimer

Dr Bonutti owns stock in Joint Active Systems, the company that designed and produced the orthosis used in the study. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article and have no potential conflicts of interest related to this manuscript.

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Appendix

Device costs

The full retail rental charge for a JAS elbow device is $395/month. Actual reimbursement through insurers is rarely the full rate, with the estimated average reimbursement for the device of $250/month. Medicare's fee schedule for JAS elbow device is approximately $129/month.

- Device cost: $592.
- 3 supervised physical therapy visits: $81 (CPT Code 97012, supervised manual traction, $27/session).
- TOTAL: $673. Three supervised therapy visits during this 6-week course would be at $673.

Physical therapy costs

Physical therapy charges vary nationwide. In central Illinois, the charge for a 15-minute manual therapy session is $55. Patients are commonly seen for at least 30 minutes, 2 to 3 times weekly for treatment of joint rehabilitation. An average session for manual therapy in Central Illinois would be $110, and 6 weeks of therapy (15 sessions) would be $1650.