Static progressive orthoses for the upper extremity: a comprehensive literature review

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Abstract

Background Static progressive orthoses are commonly used in the treatment of stiff joints or joint contractures of the upper extremity, but there are few high-quality studies to support this intervention. In addition, there has not been a recently published review of the current literature describing this treatment technique and the outcomes achieved. The specific purpose of this comprehensive literature review is to investigate the current levels of evidence supporting the use of static progressive orthoses in the treatment of joint stiffness or contracture in clients with orthopedic conditions of the upper extremity. This review will also discuss common diagnoses of patients and outcomes achieved, as well as provide recommendations for future hand therapy practice.

Methods A computerized database search of publications incorporating the use of static progressive orthoses for the upper extremity was conducted, dating from January 1979 through January of 2011. The search was limited to studies in English of adults with orthopedic conditions.

Results A total of 65 publications were located. However, only 16 of these studies met this review's inclusion criteria of level 4 evidence or above. Each of the articles was critically appraised using the Structured Effectiveness for Quality Evaluation of Study (SEQES) and the Oxford Center for Evidence-Based Medicine 2011 Level of Evidence. Total SEQES scores ranged from 17 to 39. The majority of the studies are level 4 evidence.

Conclusions Although the overall level of evidence is low, the inclusion of static progressive orthoses as an intervention appears to result in positive outcomes, including increased active range of motion, increased grip strength, improved

DASH scores, and improved patient satisfaction as well as reduced pain medications during orthotic intervention. The current evidence supports static progressive orthoses as an intervention for patients with upper extremity joint stiffness or contractures due to orthopedic conditions.

Keywords Static progressive orthoses/splinting · Mobilization orthoses/splinting · Upper extremity (including elbow, wrist, forearm, and fingers) · Contracture · Stiffness · Low load prolonged stress · Total end range time

Introduction

Therapists treating patients with limitations in joint range of motion of the upper extremity following surgery or trauma often include a variety of orthoses for mobilization into their treatment plan. Static progressive orthoses are a type of mobilization orthoses that incorporate non-elastic components to apply force to a joint to hold it in its end range position in order to improve passive joint range of motion [19]. Static progressive orthoses allow progressive changes in joint position as the passive range of motion of the involved joint changes and improves over time [14, 19].

According to Ulrich et al. [20], connective tissue is capable of being stretched due to its viscoelastic qualities. While under tension, it can respond by reaching either elastic or plastic deformation state. Elastic deformation means that the tissue reverts back to its original length when the force on it is removed. Plastic deformation means the tissue will maintain its new length even without the force. Orthoses have been used to apply this force to the tightened or shortened tissue to stretch it and lead to tissue remodeling. There are two types of loading conditions with the application of mobilizing orthoses: creep based and stress relaxation. In creep-based loading,

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the force applied is a constant force and the displacement of the limb varies. The use of low load prolonged stretch is delivered via the use of dynamic orthoses. However, there are disadvantages to creep loading. These orthoses may need to be worn for 6–12 h daily; treatment may be painful and the joint may be damaged by prolonged compression [14]. In stress relaxation, the displacement is constant and the applied force varies. This is the principle of static progressive orthoses where patients are instructed to constantly adjust and readjust the tension on their stiff joints. The tissue reaches the plastic deformation state more quickly and the effects will last longer [20]. The force from the static progressive orthosis holds the shortened tissue at its maximum tolerable length. But as this tissue length changes, the design of the orthosis also allows for changes and adjustments over time [14, 19, 20]. Static progressive orthoses are one type of mobilization orthoses utilized by therapists to improve joint passive range of motion via stress relaxation [14, 19, 20].

Important aspects of static progressive orthoses include the following:

1. Nonelastic component places tension on stiff joint to hold at its maximum tolerable length [19].
2. Adjustments to the tension on each finger can be made by the client [19].
3. The orthotic design maintains the shortened tissue at its maximal tolerable length and does not stress beyond it [19]. It is very important not to exceed the maximal tolerable stress level which could lead to tissue failure [9].
4. The longer the tissues remain at its maximum tolerable length, the more it increases in length [19].
5. Success can be measured by small gains of perhaps 5–10° a week [19].

The purpose of this comprehensive literature review is to address the following question: For patients with limitations in range of motion of the upper extremity following surgery or trauma, is the inclusion of static progressive orthoses into treatment an evidence-based intervention for improving active range of motion and ultimately function? This literature review examines the current levels of evidence supporting the use of static progressive orthoses for patients with limitations in the range of motion of the upper extremity following surgery or trauma. This review also offers relevant information on the types of diagnoses to be treated, wearing schedules, the outcomes affected, and the recommended duration of orthotic use.

Methods

A literature search of the evidence supporting static progressive orthoses for the upper extremity was performed to

identify current information regarding common diagnoses of patients treated with this type of orthotic intervention, outcomes achieved, wearing schedules, and duration of orthotic use. Literature searches of computerized databases (Pub Med, CINAHL, OT Seeker, PEDro, Google Scholar, and EBSCO) were conducted using the keywords “static progressive splinting, mobilization splinting, upper extremity (including elbow, wrist, forearm, and fingers), contracture, stiffness, low load prolonged stress, and total end range time” in various combinations. See Quorum diagram (Fig. 1). Studies were selected based on their relevance to orthotic intervention in the treatment of the upper extremity following surgery or trauma. Only studies published in English on adult patients were included in the review. Dates of the database search ranged from January 1979 through January 2011. The search was restricted to level 4 evidence or higher. Publications describing new and creative custom designs for static progressive orthoses are numerous, but were not included as these are level 5 evidence.

Results

The literature search yielded a total of 65 articles. After careful review of the abstracts, the following study types were removed from the review: duplicate studies, studies on lower extremity orthoses, studies on non-orthopedic or non-trauma patients, clinical trials of dynamic orthoses, and lower evidence level 5 papers. In the end, a total of 14 papers discussing the use of static progressive orthoses of the upper extremity were included in the review, including 12 studies and two systematic reviews. Two additional randomized clinical trials (RCTs) [6, 8] on the use of mobilization orthoses are also included in this review, for a total of 16 publications. Although these two RCTs do not describe static progressive orthoses specifically, they do provide important information on key concepts of orthotics for mobilization [6, 8]. Each of the included studies was critically appraised using MacDermid’s Structured Effectiveness for Quality Evaluation of Study (SEQES) [13]. The SEQES is a standardized form used to evaluate the quality of a study. There are 24 items on the SEQES score sheet and each item is given a score of 2, 1, or 0. The score sheets look at the quality of each study, its design, if the subjects underwent randomization or not, and if a comparison group was also included. For the items analyzed on the SEQES, see Table 1.

A score of 48 is the highest possible score. Each of the selected studies in this review was evaluated by a single reviewer, the author, (DS) for a quality score. The SEQES scores of the studies in this review received scores of 17–39, with only the two previously mentioned RCTs receiving a high-quality rating above 32. All 12 of the remaining studies were considered to be of moderate quality as explained by Valdes’ systematic review [21]. See Table 2 for the SEQES evaluation scores for quality of research.

Fig. 1 Quorum diagram for literature search

The articles were also rated according to a Sackett's Level of Evidence hierarchy using the "Oxford 2011 Levels of Evidence Table" found online at www.cebm.net [17]. See Table 3 for Oxford 2011 Levels of Evidence Table.

Discussion

Two systematic reviews include studies using static progressive orthoses and are rated level 1 evidence according to the Oxford 2011 Levels of Evidence Table [17]. Farmer and James [5] searched for therapeutic interventions to treat contractures resulting from muscle weakness, spasticity, and immobilization. Their review looks at the effects of passive stretching, continuous passive motion, electrical stimulation, botulin injections, surgery, and different types of orthotic intervention. The authors state that serial static orthoses have the ability to hold the joint and surrounding tissue in a fixed position but this stretch is not maintained when the force is removed. They note the benefits of

mobilization orthoses that can be used for longer periods of time and removed to allow for stretching of the hold of the affected joint at the limit of range. These orthoses offer the ability to provide continuous stretching during the application.

In their systematic review, Michlovitz et al. [16] examine different therapeutic techniques to improve range of motion. The authors cite a total of nine studies that describe orthotic intervention, including the use of static progressive orthoses, as a method for improving range of motion. Two studies looked at the use of turnbuckle orthoses to help increase range of motion in elbow contractures. The authors conclude that although the majority of the published evidence on orthotic intervention is from lower level studies, there is consistent support for the benefits of orthoses to increase range of motion. They note that more evidence is needed to determine best practice of orthotic usage and type.

There are no randomized clinical trials on the use of static progressive orthoses in the upper extremity. Most of the evidence comes instead from retrospective studies or case series. However, two important RCTs help explain an important

Table 1 Items analyzed on the Structured Effectiveness for Quality Evaluation of Study (SEQES)

Background
1. Relevant background work
Design
2. Comparison group
3. More than one time point
4. Prospective data collection
5. Randomization of patients
6. Blinding of patients
7. Blinding of providers
8. Independent evaluator
Participants
9. Minimal sample/selection biases
10. Inclusion/exclusion criteria
11. Appropriate enrollment
12. Appropriate follow-up
Treatment
13. Established intervention
14. Treatment provider training
15. Comparison treatment
Outcomes measures
16. Primary outcomes
17. Secondary outcomes
18. Appropriate follow-up
Statistical analysis
19. Appropriate statistical tests
20. Significant power
21. Effect size and significance
22. Missing data
23. Clinical and practical significance
Results
24. Conclusions
Total quality score (sum of above/48)

concept of static progressive orthoses, the concept of total end range time (TERT), and are therefore included here. Both the original study of TERT by Flowers and La Stayo [6] and a 2003 study by Glasgow et al. [8] highlight the fact that the higher gains in the range of motion were made when the mobilizing orthoses were worn for longer periods of time. These studies used other forms of mobilization orthoses specifically serial static orthoses [6] and dynamic orthoses [8].

In the Flowers and La Stayo study, 15 patients with 20 contractures wore serial casts for correction of proximal interphalangeal joint (PIP) flexion contractures. Those patients that wore the casts for 6 days straight demonstrated significantly improved passive range of motion over patients who wore casts for 3 days straight [6]. In the Glasgow et al. study, 43 patients using dynamic orthoses for PIP or metacarpal–phalangeal joint contractures wore these orthoses for either 6 h or 6–12 h. Those

in the longer wearing time frame demonstrated significantly more passive joint range of motion [8]. Although these studies utilized serial casting or dynamic orthoses to achieve the end result, the important principle of TERT outlined here also applies to static progressive orthoses as well. The groups with the higher TERT achieved better contracture resolution than the group with the lower TERT.

The 12 studies under review (not including the two previously mentioned RCTs and two systematic reviews) comprise a total of 302 patients. Patient diagnoses include elbow fractures (radial head, ulna, and distal humeral fractures), wrist fractures (distal radius and ulna fractures), fracture dislocations, lacerations, tenosynovitis, sprains, crush injuries, general stiffness after surgery or trauma, and joint contractures.

Types of Orthotic Designs

Three studies look at the use of a custom-made orthosis, four studies investigate turnbuckle orthoses, and five studies review the use of commercially available Joint Active System (Joint Active System, Inc. Effingham, IL) (JAS) orthoses. Three studies review the JAS orthosis for the wrist, and two studies review the JAS orthosis for the elbow. The four turnbuckle studies cited incorporate an orthosis for the elbow [2, 4, 7, 10]. Custom-made static progressive orthoses were fabricated for the elbow in the study by Alcansak et al. [1] and for forearm motion in the study by Parent-Weiss and King [18] and in the study by McGrath et al. [15].

Patients using the custom-made orthoses were instructed to wear for long sessions throughout the day and night. The instructions for the turnbuckle orthoses were to wear it for as long as possible, even up to 15–20 h per day. The orthosis could be removed for meals and for a minimum of exercise. The JAS system makes specific recommendations for the wearing schedule, so the five studies using JAS orthoses followed a similar schedule [3, 11, 12, 14, 20]. The recommended schedule started with one 30-min session per day for the first week and increasing up to three times per day by the third week. In addition, patients were instructed to increase the tension on the affected body part every 5 min while wearing the orthotic device.

Treatment Protocols and Duration of Use

In most of the studies, the splinting protocol was patient specific and varied from patient to patient. The general approach was half an hour in each direction (flexion and extension) three times a day.

McGrath et al. [15] conducted a study of 38 patients using static progressive splinting to restore forearm motion. The

Table 2 SEQES evaluation scores for quality of research

	Citation	Year	Level of evidence ^a	SEQES score
	Alsancak et al. [1]	2006	Level 4	Score 17
	Bhat et al. [2]	2010	Level 4	Score 20
	Bonutti et al. [3]	1994	Level 4	Score 23
	Doomberg et al. [4]	2006	Level 4	Score 29
	Farmer and James [5]	2001	Level 1	Systematic review
	Flowers and LaStayo [6]	1994	Level 2	Score 34
	Gelinas et al. [7]	2000	Level 4	Score 19
	Glasgow et al. [8]	2003	Level 2	Score 39
	Green and McCoy [10]	1979	Level 4	Score 19
	Lucado et al. [12]	2008	Level 4	Score 28
	Lucado and Li [11]	2009	Level 4	Score 25
	McGrath et al. [14]	2008	Level 4	Score 30
SEQES Structured Effectiveness for Quality Evaluation of Study	McGrath et al. [15]	2009	Level 4	Score 26
	Michlovitz et al. [16]	2004	Level 1	Systematic review
^a The Oxford 2011 Levels of Evidence. Oxford Centre for Evidence-Based Medicine	Parent-Weiss et al. [18]	2006	Level 4	Score 17
	Ulrich et al. [20]	2010	Level 4	Score 26

authors prescribed a splinting regimen of 30–60 min of splint use, one to three times a day for 12 weeks [15].

Lucado et al. [12] looked at static progressive splinting for stiffness in 25 patients seen after distal radius fractures. During the first week, patients were instructed to perform one 30-min session of splint use per day, increasing to two 30-min sessions per day in the second week and three 30-min sessions per day for the remaining weeks. Splint use continued for 12 weeks duration on average.

In an additional study, McGrath et al. looked at 47 patients with limitations of wrist motion [14]. Patients wore a bidirectional static progressive wrist splint for an average of 3 h per day for 10 weeks. Patients were instructed to place the orthosis on their involved wrist and adjust the tension so they could feel a pain-free stretch. They were to readjust this stretch every 5 min for a total of 30 min and then do for the opposite direction. Each session lasted about 1 h and patients performed a maximum of three sessions per day. Splint use continued for a total of 10 weeks (range of 5–26 weeks).

Gelinas et al. looked at 22 patients with elbow contracture [7]. The patients began using a static progressive turnbuckle splint which was worn an average of 15 h per day. Splinting

was continued on average for 4.5 months (± 1.8 months). Doomberg et al. conducted a retrospective study over a 3-year period on 29 consecutive patients with elbow stiffness after trauma [4]. Patients used the commercial JAS splints, on average for 4 months (1–9 months).

Outcome Measures

The researchers looked at a variety of outcomes including active and passive range of motion, function, grip strength, and patient satisfaction. Outcome measures for the study by Lucado et al. [12] included range of motion measures for wrist and forearm, grip strength, and DASH (Disabilities of the Arm, Shoulder, and Hand) scores. An added benefit of static progressive splint use was improved grip strength (mean of 24.5 lbs) and an improved DASH score. The median DASH score, a measure of perceived disability, improved from 43 to 19 after orthotic intervention.

McGrath et al. reported on wrist range of motion and patient satisfaction after the use of static progressive orthoses in his cohort of patients with wrist stiffness [14]. There was an increase in wrist arc of motion from 67° on average to 101°. Final patient satisfaction was rated on a ten-point Likert scale with the average score being 8.2. Ulrich et al. also looked at the use of pain medication during orthotic intervention in their cohort of patients with elbow contractures [20]. No additional pain medications were needed, and overall, the use of pain medications decreased at the end of treatment. A summary of the evidence from the studies is presented in Table 4: Summary of evidence for static progressive orthoses in the upper extremity.

Table 3 Oxford 2011 levels of evidence table

Level 1	Systematic review
Level 2	Randomized clinical trial
Level 3	Non randomized controlled study
Level 4	Case series/case report
Level 5	Expert opinion

Found online at www.cebm.net

Table 4 Summary of evidence for static progressive orthoses in the upper extremity

Reference	Body part	Diagnosis	Type of splint	Number of patients	Wearing schedule	Duration of splinting	Outcomes
Alsancak et al. [1]	Elbow	Fractures, burns resulting in elbow flexion contractures	Custom	5	Week 1, 6 h total, 2 h on 30 min off. Week 2, 2 patients wore at night and 3 patients wore full time (with 3×1 h breaks) 15 h of wear	2.2 months	Improved MMT and increased ROM
Bhat et al. [2]	Elbow	Fractures, nerve surgery, dislocations	Turnbuckle	28		5 months	Increased ROM
Bonutti et al. [3]	Elbow	Contractures	Joint Active System (JAS)	20	30 min every 5 min adjustments made to tension, additional 30 min sessions added every week of treatment	1–3 months	Increased ROM, increased patient satisfaction, average increase 31° (17° in extension and 14° in flexion)
Doornberg et al. [4]	Elbow	Stiffness after trauma	Turnbuckle	29			Increased ROM.
Flowers and LaStayo [6]	Finger PIP joint	PIP contracture	Serial casting	15 ^a	Group 1, 6 days casting, then 3 days casting. Group 2, 3 days casting, then 6 days casting	9 days	Higher TERT = higher gains in ROM
Gelinas et al. [7]	Elbow	Contractures	Turnbuckle	22	20 h per day, removed for 1 h periods 4 times per day for exercise, alternating positions of flexion and extension	average of 4.5 months	Average gain in flexion of 20°±15° 11 patients gained functional arc of motion, 8 patients improved their arc, 2 went on to a release procedure, 3 patients had no improvement.
Glasgow et al. [8]	Finger PIP	Finger contractures	Dynamic splinting	43 ^a	Group A, 6 h/day. Group B, 6–12 h/day	until significance was reached	Higher TERT = higher gains in ROM
Green and McCoy [10]	Elbow	Fractures, dislocations, fracture dislocations, postoperative stiffness, medial epicondylectomy, laceration, tennis elbow	Turnbuckle, custom made	15	As much as possible, remove for range of motion exercises or full time	3 weeks to several months	Increase in elbow extension by average of 37°, increase in arc of motion by 43°
Lucado and Li [11]	Wrist	Distal radius fractures resulting in persistent wrist stiffness	Joint Active System (JAS)	8	Week 1–30 min/day; week 2–2×30 min; week 3–3×30 min, and continue 3x/day for 30 min.	88 days (21–180)	Increased range of motion, active and passive, improved DASH, duration of splint wear, number of treatments
Lucado et al. [12]	Wrist	Distal radius fractures	Joint Active System (JAS) for pronation/supination [6] wrist flexion/extension [19]	25	Week 1–30 min/day; week 2–2×30 min; week 3–3×30 min, and continue 3×30	75 days	Increased ROM, grip, and improved DASH scores
McGrath et al. [15]	Forearm	Distal radius fractures, radial head fractures, humeral fractures, ulna fractures, wrist sprains, tenosynovitis, carpal bone fractures, and contractures	Patient applied bidirectional supination/pronation	38	1–3 x/day for 30 min, every 5 min, adjust tension	12 weeks average	Increased ROM (mean of 42°, 12° pronation, 31° supination, satisfaction improved)

Table 4 (continued)

Reference	Body part	Diagnosis	Type of splint	Number of patients	Wearing schedule	Duration of splinting	Outcomes
McGrath et al. [14]	Wrist	Trauma or surgery of the wrist	Joint Active System (JAS)	47	30–60 min, 2–3 x/day	10 weeks average	Increased ROM, increased patient satisfaction
Parent-Weiss et al. [18]	Forearm	Elbow fracture dislocation, radial head injury, distal radius fractures, wrist ligament injuries, ulna injury	Custom for forearm rotation	28	6–8 h during sleep, 3–4 h, 3 x/day, 1–2 h off for functional activities, sub-maximal stretch	12–14 weeks	Increased ROM, average gain in supination was 36.5°, average gain in pronation was 25.8°
Ulrich et al. [20]	Elbow	Posttraumatic elbow contractures	Joint Active System (JAS)	37	30 min/3 x a day	10 weeks on average	Increased elbow motion, increased patient satisfaction (11-point Likert scale), decreased use of pain medication

^aNot included in total number of patients

The current evidence on static progressive orthoses notes the following benefits:

1. Improved range of motion without pain; high tolerance for orthotic use because the patient can control the force of the tension; higher compliance; and higher patient satisfaction result.
2. The patient is able to adjust the tension force gradually, as this type of orthotic intervention takes advantage of small incremental changes in tissue length.
3. The optimum orthotic design allows for small changes in joint motion without remodeling of the orthosis each time gains in range of motion are accomplished.

There were no randomized clinical trials on static progressive orthoses versus dynamic orthoses for upper extremity trauma or postsurgical patients found in the literature search performed here. In addition, there were no studies comparing custom-made static progressive orthoses to commercial static progressive orthoses. These topics may be addressed in future clinical studies.

There are a number of limitations to the aforementioned studies. As noted, there are no true randomized clinical trials on the use of static progressive orthoses. The existing evidence is found in retrospective studies or case series. Only a small number of patients have been enrolled in these studies. The types of orthotic intervention and the treatment protocols vary, making it difficult to recommend a specific type of orthosis design or a treatment protocol. Also, patient diagnoses differ from study to study making it difficult to compare actual limitations and treatments. However, the information gleaned from these low level studies can be used as a basis to generate treatment protocols for future patients.

Implications for the Future

Following are the implications gleaned from the studies for future hand therapy practice:

1. There is moderate evidence to support this orthotic intervention, although there are no set parameters on wearing schedules and/or duration of orthotic intervention.
2. Candidates include patients seen after fractures of the humerus, radius, ulna, and carpal bones; fracture dislocations; ligament injuries and sprains; tenosynovitis and tennis elbow; and trauma and patients with residual joint stiffness and/or contracture after upper extremity surgery.
3. There is a wide selection of commercial orthoses and designs for custom orthoses available.
4. Longer wearing times with frequent adjustment of tension appears to be a commonly employed protocol.

5. The use of static progressive orthoses to regain joint motion is an important intervention of hand therapy treatment.
6. There is a need for continued research and clinical trials.

Conclusion

This comprehensive literature review examined and rated the existing evidence supporting the use of static progressive orthoses for treatment of upper extremity joint stiffness and/or contracture in patients with limitations in joint range of motion. The current evidence is found in lower level retrospective studies and case series. These studies have moderate level quality scores. However, the evidence from these studies demonstrates a clear trend towards positive outcomes following the use of static progressive orthoses.

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