

# Dynamic Splinting for Contracture Reduction: A Review

by Buck F. Willis MBB,S PhD<sup>1</sup>✉ and Sarah A. Curran PhD, BSc(Hons), FCPodMed, FFPM RCPS(Glas) FHEA<sup>2</sup>

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**Background:** Contracture is molecular shortening of connective tissue(s) which arise from orthopedic, neural, and idiopathic origin. It affects the joints from temporo mandibular to metatarsophalangeal joints, affecting over 250,000 new patients globally each year.

**Objectives:** The purpose of this literature review was to examine studies on contracture reduction of the knee, ankle and toe, with descriptions of the biomechanics of the Dynasplint systems biomechanics.

**Methods:** A literature review of Dynamic Splinting and knee, ankle, toe was completed to examine the most recent and pertinent studies on contracture reduction, published since 2007.

**Discussion:** Dynamic Splinting employs prolonged, passive stretching with dynamic forces to achieve increased time at end-range of motion. The literature reviewed has shown efficacy of this treatment protocol in treating contracture. The biomechanics of this modality have been thoroughly reviewed and justified.

**Conclusion:** Dynamic splinting should be included in standard of care for contracture reduction of the lower extremity.

**Key words:** Connective Tissue, Dynasplint, and Range of motion

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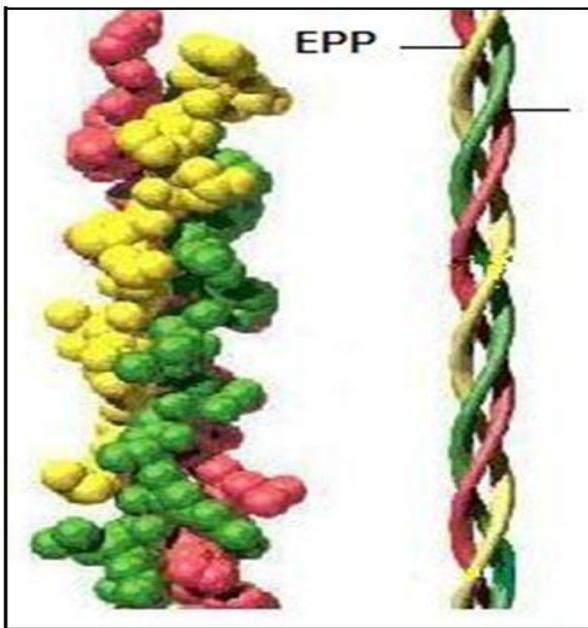
Contracture is a molecular shortening of connective tissue<sup>1-20</sup> which includes realignment of elastin polypeptide chains along the collagen triple helix.<sup>1-4</sup> (Fig. 1) Contracture is caused by joint positioning (immobilization), arthrofibrosis, neural injury or disease, obstruction/impingement (osteocytes) and idiopathic origin. Conditions such as Dupuytren's contracture,

adhesive capsulitis and toe walking can be examples of such idiopathic pathologies. (Fig. 2) The purpose of this literature review was to examine studies on contracture reduction of the knee, ankle and toe, with descriptions of the biomechanics of the Dynasplint systems biomechanics.

Dynamic splinting can deliver various stretching options (prolonged or short duration with high or low intensity of force to counteract the contracture. One keystone experiment to determine which combinations were the most effective was conducted by Usuba, et al.

**Address correspondence to:** <sup>1</sup>Buck F. Willis, Assistant Professor, McMurry University, Box 188, Abilene, Texas, USA79697. Email: [willis.buck@mcm.edu](mailto:willis.buck@mcm.edu) Phone: 325-793-4993.

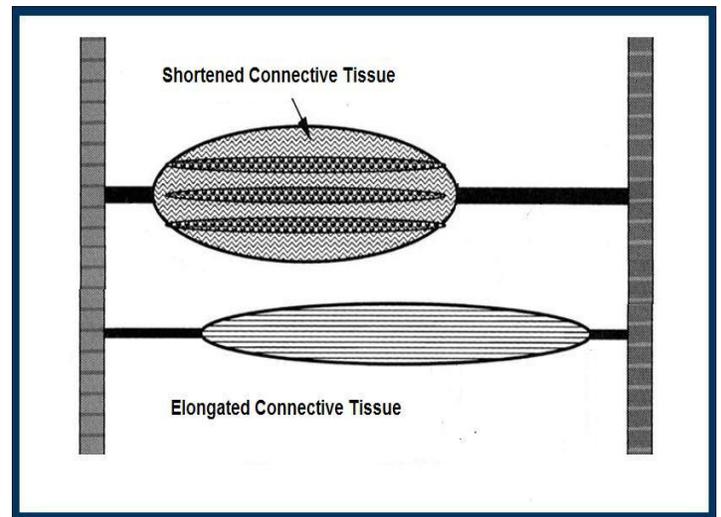
<sup>2</sup>Sarah A. Curran, Senior Lecturer, Wales Centre for Podiatric Studies, Cardiff Metropolitan University, UK.



**Figure 1** Collagen and elastin polypeptide.

This randomized trial surgically immobilized 66 rat knees ( $-30^\circ$  extension) and measured contracture following 40 days of immobilization (mean  $-45^\circ$  extension) to determine the difference between combinations of stretching protocols for increasing the range of motion (ROM).<sup>1</sup> The rats were separated into different groups for varied stretching protocols (prolonged vs. short duration and high vs. low torque, force), and the stretching phase lasted for a 4-week period. All protocols showed improved ROM and the only significant difference between protocols was from the combination of prolonged duration of stretching with low-torque of force.<sup>1</sup>

Numerous other studies have examined clinical efficacy of passive stretching<sup>5-9</sup> including a systemic review by Harvey, et al.,<sup>6</sup> which showed efficacy in prolonged, passive stretching for increasing ROM (although limited power did not allow a meta analysis). Studies employing prolonged durations of stretching have enlightened clinicians and allowed surgeons to avoid manipulation under anesthetics to surgically reduce contracture. Patients with neural pathologies or injuries often acquire contracture secondary to unmanaged hypertonicity frequently from damage to the dorsal root ganglia.<sup>7-10</sup>



**Figure 2.** Shortened connective tissue.

Plaster serial casting has long been used in contracture reduction. Singer et al examined serial casting in patients who have suffered traumatic brain injuries (TBI). This study showed that following an 18 month period, none of the patients' contracture had completely reduced and that 18% of patients began losing the regained ROM within weeks after the final cast was removed.<sup>7</sup> While the duration of prolonged stretching required to prevent or reduce contracture is unknown, Dr. Singer hypothesized that the duration required for reduction equates to the duration of development and *"It remains to be seen whether a more proactive approach to the amelioration of dystonic muscle overactivity and maintenance of muscle length and soft tissue extensibility can prevent the development of ankle deformity"*.<sup>8</sup>

Glasgow, et al., questioned whether static serial splinting (like serial casting), or static progressive splinting or dynamic splinting would be the most effective. Their literature review concluded that prolonged duration of end-range stretching is optimal for contracture reduction because *"Dynamic splints may have greater potential to maximize the time that the joint is actually held at optimal end range, promoting greater tissue growth and subsequent contracture resolution"*.<sup>9</sup> Ada, et al., completed a study examining prolonged positioning for prevention of contracture of the shoulder in stroke patients.



**Figure 3** Knee Extension Dynasplint.

Their randomized study showed that prolonged positioning (30 minutes per day for six weeks) was effective in maintaining maximal external rotation in experimental subjects.<sup>10</sup>

Lai, et al., examined dynamic splinting in a controlled, cross-over study treating both TBI and stroke patients. All patients in this study began as control subjects being treated only with manual therapy (2/wk for 3 months) and selected patients were crossed-over for treatment with the Ankle Dorsiflexion Dynasplint (AFD; Dynasplint Systems Inc, Severna Park MD, USA). The cross-over patients were treated with AFD for an additional 90 days showed a mean improvement in maximal dorsiflexion of 19° vs. the control patients lost ROM with a mean -8° change after the total 180 day study.<sup>11</sup> This difference was attributed to the duration of total end range stretching which exceeded 620 hours for the experimental patients treated with the AFD vs. less than 25 total hours of stretching (control) when treated with manual therapy alone.

## Methods

A literature search was performed through Medline and PubMed using a combination of subject heading and text word search strategy to retrieve manuscripts published addressing the use of dynamic splinting and contracture reduction in joints of the lower extremity. A secondary search was performed to acquiesce similar manuscripts in *contracture reduction*, published since 2000.

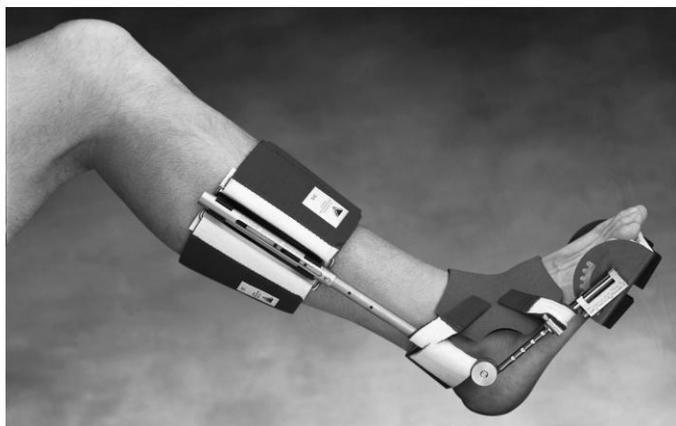
## Mechanics of Dynasplint Systems

The mechanics employed by Dynasplint systems are most clearly seen in the Knee Extension Dynasplint system (KED). (Fig. 3) The low load, prolonged duration of end-range stretching is accomplished through a biomechanically correct application of force and counter force. A bilateral, spring loaded tension system applies an equal amount of force across the joint line and maintains proper anatomical alignment even as the tension is increased. This force is measurable, replicable and sequentially increased to adapt to changes in end range of motion.

Hypoallergenic straps secure the KED to each patient's leg and the initial fitting is accomplished by a Dynasplint specialist who also trains the patient on donning and doffing the modality and how to accomplish the sequential tension changes every two weeks. Patients are instructed to wear the KED for 6-8 hours continuously while sleeping. Patient compliance is typically high because the unit is comfortable and patients quickly feel the benefit in their activities of daily living (ADL). A case reported by Finger and Willis showed such compliance.<sup>12</sup>

## Knee Extension Dynasplint

A 61 year-old male underwent a total knee arthroplasty (TKA) and post-operatively his maximal ROM was -20° of knee extension. This is attributed to post-operative arthrofibrosis.<sup>1,3,6,12-15</sup> After 20 of 28 physical therapy sessions (scheduled over two months), the patient reached a plateau of -12° knee extension. Following two additional months with KED (100% compliance), the patient regained full ROM (0°) in knee extension.<sup>12</sup> A retrospective study by Armstrong and Willis questioned the initial time required in a KED to see a significant change in ROM. Studying 107 patients showed a statistically significant change after one month ( $p < 0.001$  and mean  $\Delta 8^\circ$ ).<sup>13</sup> All but 5 of these patients regained full extension and none of the patients in the retrospective study required manipulation under anesthetics which is commonly used to treat a significant number the 40% contracture seen following TKA. Prolonged stretching of dynamic splinting has also been used proactively to prevent the expected contracture following knee surgery.<sup>14,15</sup>



**Figure 4** Ankle Dorsiflexion Dynasplint.

### Ankle Dorsiflexion Dynasplint

Ankle contracture is common from similar causes of immobilization, arthrofibrosis, neural onset and idiopathic origin.<sup>3,6-8,11-19</sup> Malleolar fractures are treated with immobilization and/or surgery which show a significant occurrence of contracture. Curran and Willis<sup>16</sup> examined patients who had chronic contracture (more than 12 months) following ankle fractures before being treated with the Ankle Dorsiflexion Dynasplint (AFD). (Fig. 4) Even though other treatment methods had been exhausted for these patients, use of the AFD for low load, prolonged duration of passive stretching accomplished a mean 23.4° improvement in 16 weeks with incremental tension changes every two weeks.

Ankle equinus is defined as a 10° deficit in dorsiflexion during the stance phase of gait, and it is common secondary to diabetes mellitus. Whilst there is a range of methods for treating ankle equinus, many findings remain inconclusive.<sup>16, 17</sup> It can be argued that the only proven method for reducing this contracture is surgical tendon lengthening. Lopez, et al., conducted a study of AFD treatment for reducing this contracture which affects patients' gait pattern, injuries, infection and ultimately effects limb preservation in diabetic patients. Durations of treatment varied in this retrospective study (1-6 months) so the first month was examined for uniformity. In the first month patients regained a mean 9° in dorsiflexion which was a significant change for these 48 patients, ( $p < 0.0001$ ).

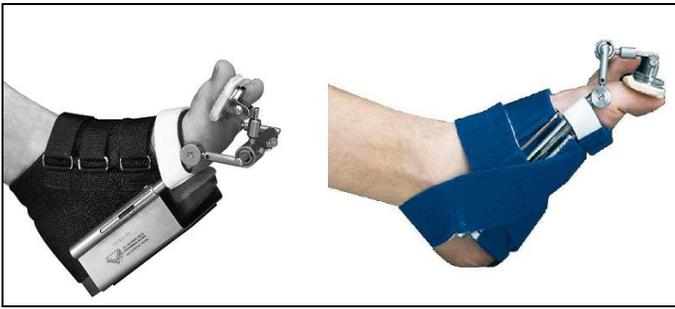
<sup>17</sup>

Plantar fasciopathy (PF) is considered the most frequent cause of acute heel pain in the United States. It was hypothesized that prolonged passive, end range stretching would benefit this condition.<sup>18</sup> Sixty patients (76 feet) diagnosed with PF (acute heel pain worsening upon rising, paresthesia after non weightbearing, etc) were enrolled in the multi-centre trial conducted by Sheridan et al. Exclusion criteria included calcaneal bursitis, stress fractures, tarsal tunnel syndrome and other related pathologies. The duration of this trial was 12 weeks and the experimental patients fit with the AFD had a mean 33 point reduction in the 100 point ADL Plantar Fasciitis pain scale vs. the control patients who displayed a mean 2 point rise in pain scale scores). ( $t_{56} = -8.734$ ,  $p < 0.001$ )<sup>18</sup>

### Metatarsal Dynasplints

Hallux limitus is a pathologic condition of limited range of motion that leads to degenerative arthritis. Hallux limitus is commonly seen following bunionectomy and cheilectomy procedures of the first metatarsal joint (MTJ). The biomechanical apparatus of dynamic splinting for contracture reduction of the MTJ is similar with force, counter force and measurable dynamic tension, but the Metatarsal Dynasplint (MDS) employs shorter treatment duration.

John, et al., completed a randomized, controlled trial examining reduction of hallux limitus originating secondary to cheilectomy and bunionectomy.<sup>21</sup> (Fig. 5) The current standard of care for hallux limitus includes analgesic and non-steroidal anti-inflammatory drugs (NSAIDs), orthotics (shoe inserts) and home stretching exercises. All patients received these treatments, and in addition, experimental patients were also treated with the MTJ Extension (while seated) 60 minutes, three times per day. The dependent variable in this study was change in maximal active range of motion (AROM) in extension (after eight weeks treatment). The results showed a significant difference between change in AROM between Experimental vs. Control ( $p < 0.0001$ ,  $t = 4.224$ ,  $n = 48$ ,  $df = 47$ ; range -10° to +60°). Experimental patients displayed a 32° improvement in maximal extension compared to only 10° improvement for control patients. No significant difference was shown between bunionectomy vs. cheilectomy patients.<sup>21</sup>



**Figure 5** Metatarsal Dynasplint extension and flexion.

To see how gait is affected by runner's toe, John, et al., demonstrated in a case report with gait analysis of an international marathon runner suffering from chronic extension contracture of the MTJ. The patient, a 47 year-old, Caucasian male, had been a competitive runner for 30 years. It was hypothesized that repeated, micro-trauma contusions were the cause of his hallux rigidus. Before treatment with the MDS, his maximal AROM in flexion was 0° compared to 55° flexion in the asymptomatic great toe. The MDS treatment for this patient lasted four months, (60 minutes, three times per day) and gait testing (pre/post) was accomplished with VICON MX system (workstation, polygon, Butterworth filter, and force plate) (Vicon UK, Oxford, England). Following treatment with MDS, beneficial changes were seen in cadence, time aloft, external ankle rotation and ROM of the MTJ. The static, maximal AROM of the symptomatic toe improved from 0° of flexion to 50° flexion after four months in the MDS.<sup>22</sup>

Kalish and Willis wished to see the effect of hallux limitus reduction on a broader population and to determine if there were different initial changes between hallux limitus of bunionectomy vs. cheilectomy vs. contusion. They conducted a retrospective cohort study of 61 hallux limitus patients from multiple sites with a dependent variable of change in AROM with independent variables of categories: bunionectomy vs. cheilectomy vs. contusion. A significant change was seen in all patients ( $n=61$ ,  $p<0.001$ ,  $t=30.079$ ,  $df=60$ ) but the repeated measures ANOVA did not show a significant difference between categories ( $p>0.05$ ).<sup>23</sup>

Patients regained a mean 73% (increase) in dorsiflexion at the first MTJ of the hallux in just one month. MDS utilizes a biomechanical adaptation to achieve a physiological change in contracture reduction of the connective tissue.

## Discussion

These studies have shown a conclusive benefit from applying prolonged duration of passive stretching with a low load, measurable dynamic force in contracture reduction. A leading textbook for doctoral physical therapy students, *Therapeutic Exercise, Moving Toward Function, 3<sup>rd</sup> Ed.* (Brody and Hall) discussed use of dynamic splinting as a therapeutic adjunct for treating contracture.<sup>20</sup> This text specifically describes how contracture occurs following prolonged immobility and that Dynasplint Systems "*Low-torque, long-duration stretching produced better outcomes than short-duration, high-torque activities.*"

Serial casting has been a mainstay for contracture reduction but even after 18 continuous months in ankle casts, patients' regained ROM began deteriorating within weeks of the cast removal.<sup>7</sup> This shows that while serial casting may only have short term efficacy. In comparison, the retrospective KED study of patients following TKA showed that 98% of the patients regained full restoration of knee extension and in 12 months following TKA, none of the 107 patients required manipulation under anesthetics to reduce contracture.<sup>13</sup>

Molecular development of contracture is similar despite the causing pathology or injury and reduction of contracture can be equally effective using joint specific dynamic splinting. Dynasplint Systems deliver a low load, prolonged duration of passive stretching with measurable dynamic tension and this should be included in the standard of care in contracture reduction.

## Competing Interests

Sarah A. Curran is the Chief Editor and Buck F. Willis is the Associate Editor-in-Chief of the *Foot and Ankle Online Journal* and were removed from the peer review process and editorial decision for this manuscript. Buck F. Willis is employed by the parent company of Dynasplint Systems, Inc, but has no stock or ownership in either company and receives no compensation for this publication. Sarah A. Curran has no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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