

# "JOINT CONTRACTURE REHABILITATION: STATIC PROGRESSIVE STRETCH"

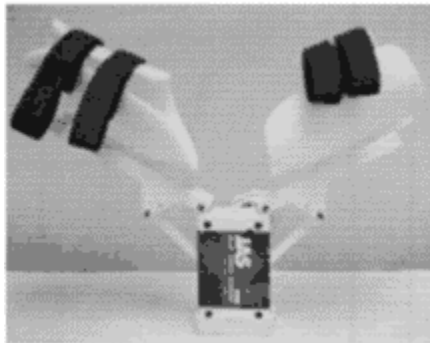
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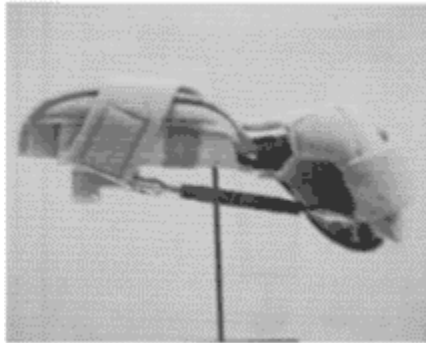
## **INTRODUCTION**

Restoration of functional Range of Motion (ROM) is one of the primary goals of most rehabilitation programs. Restoring ROM in a time efficient manner remains an extremely challenging problem faced by orthopedic surgeons and other practitioners. Two different treatment options currently available to the practitioner include Stress Relaxation based modalities such as static progressive splints (SPS) (Fig. 1), manual traction and turnbuckles (Fig. 2) and Creep based modalities such as dynamic splinting (Fig. 3 & 4) and bucks traction.

**FIGURE 1:  
STATIC PROGRESSIVE  
SPLINT**

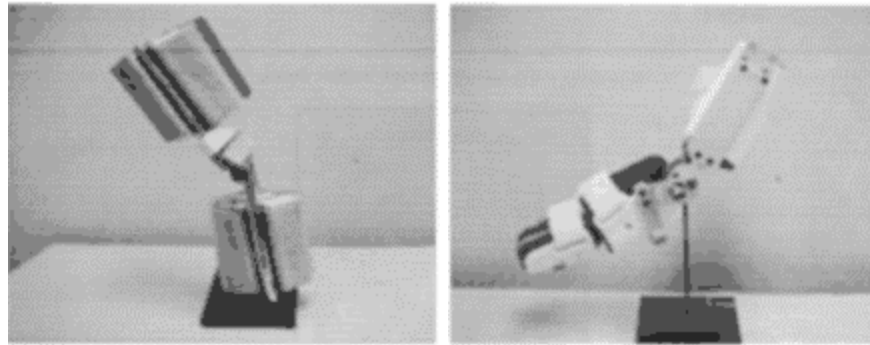


**FIGURE 2:  
TURNBUCKLE**



**FIGURE 3:  
DYNAMIC TENSION  
SPLINT**

**FIGURE 4:  
DYNAMIC TENSION  
SPLINT**



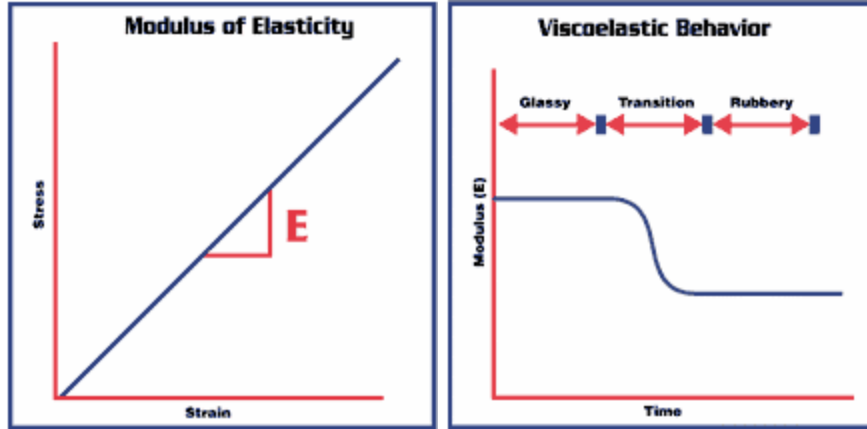
The Creep based modality systems have been the most utilized. However, these Creep based devices require a longer wearing time for the patient (8-12 hrs. per day) and a lengthy overall treatment period. This study investigated a different approach to the treatment of ROM limitations and the efficiency of SPS vs. Creep from two perspectives. The first was cumulative application time to full recovery or Total Treatment Time (TTT) which measured the time a patient underwent the treatment on an hourly basis. The second method was treatment days (TD) to discharge, which used total days as the standard of comparison for clinical efficacy. Temporary side effects (tissue irritation and skin breakdown) and their effects on outcomes and compliance was also monitored.

## **BACKGROUND**

Tissue behaves in a viscoelastic manner when subject to mechanical loading conditions. Since rehabilitation of ROM problems involves externally applied loads of displacements, it is essential to understand viscoelasticity on both an experimental and theoretical level. Modulus of elasticity is an engineering term that essentially is a way to describe the stiffness of a material It is defined as the ratio of Stress to Strain (Fig. 5). A material with a higher modulus is stiffer than a material with a lower modulus. Viscoelastic materials go through three states of material property as loads are applied. The first is a glassy or brittle state (high modulus), the second is a transition phase, and the third is a rubbery or ductile state (low modulus)(Fig. 6).

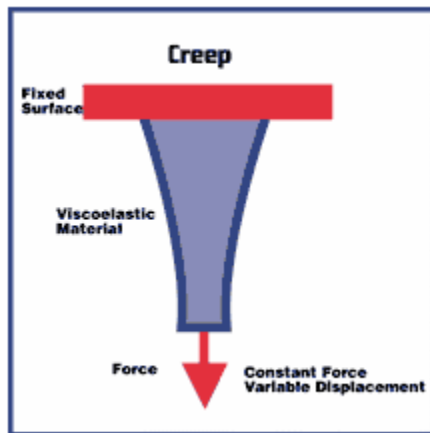
**FIGURE 5:**

**FIGURE 6:**

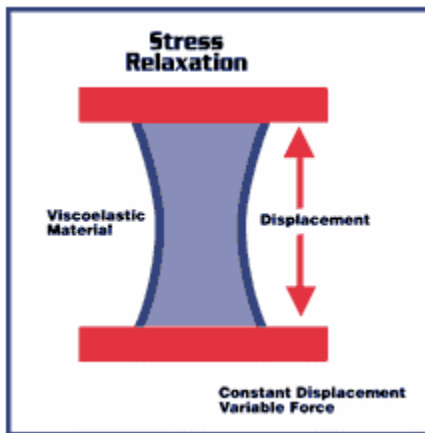


Creep is a loading condition where a constant force is applied to a material over a long period of time. Thus force or load is held constant while the displacement is allowed to vary (Fig.7). Stress Relaxation is another loading condition that can be applied to a viscoelastic material. The subject material is held in a fixed displacement. Thus displacement is constant while the force is allowed to vary (Fig. 8). With SPS, a series of incremental increasing displacements are held constant over a prescribed period of time (Fig.9).

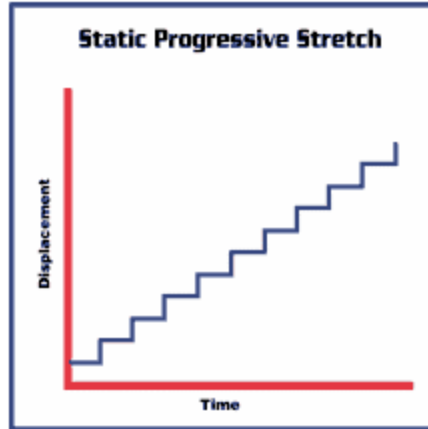
**FIGURE 7:**



**FIGURE 8:**



**FIGURE 9:**



Biomechanical investigation identifies Stress Relaxation as the most efficient way to produce a permanent elongation of soft tissue. Incorporating SPS allows the tissue to reach a more ductile state faster than when Creep is employed. It is more efficient to achieve plastic deformation while viscoelastic material (Tissue) is in this rubbery state. Once plastic deformation of tissue is attained, it is maintained.

Utilizing Stress Relaxation and Creep equations for a standard linear solid model (Fig. 10, 11), and plotting the Stress Relaxation modulus and Creep modulus as a function of time, an interesting result is apparent (Fig. 12). The Stress Relaxation modulus drops from a high glassy value to a low ductile or more pliable value sooner than the Creep modulus. Our mathematical modeling predicts that when Stress Relaxation loading conditions are employed, a viscoelastic material becomes softer and more pliable sooner than when Creep is employed.

**FIGURE 10:**

**Stress Relaxation Modulus as a Function of Time**

$$E_{rel}(t) = k_e + k_1 e^{-\frac{t}{\tau}}$$

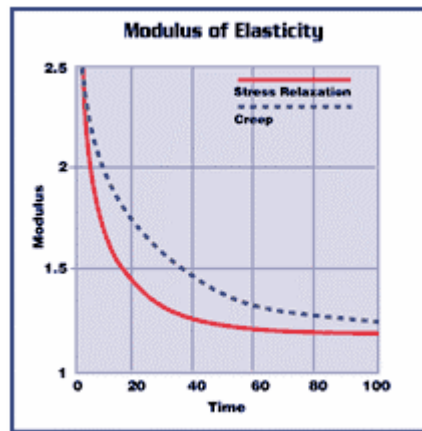
**FIGURE 11:**

### Creep Modulus as a Function of Time

$$D_{crp}(t) = \frac{1}{k_e} + \left[ \frac{1}{k_e + k_1} - \frac{1}{k_e} \right] e^{-\frac{t}{\tau}}$$

$$E_{crp}(t) = \frac{1}{D_{crp}(t)}$$

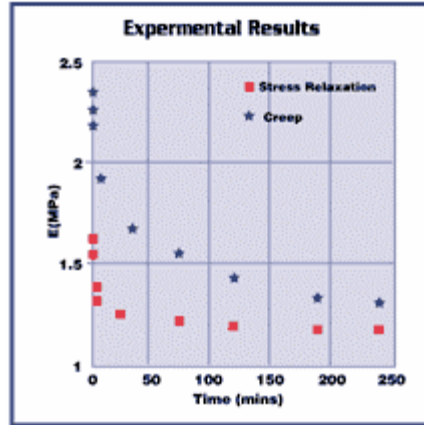
FIGURE 12:



## BIOMECHANICAL TESTING

We performed a series of studies on a model viscoelastic material and employed an MTS Bionix Materials Testing System to conduct Stress Relaxation and Creep experiments. We monitored both Stress Relaxation and Creep moduli as a function of time. We then plotted the results (Fig. 13). Our experimental results confirmed our mathematical predictions that when Stress Relaxation is employed, a viscoelastic material becomes softer or more pliable sooner than when Creep is employed.

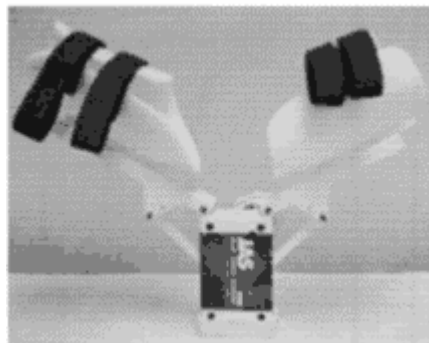
FIGURE 13:



## METHOD

Information was gathered from published literature listing TTT, TD and ROM improvement data. Studies were also reviewed for complications directly attributed to the treatment, and patient compliance information. Modalities reviewed included dynamic splinting, turnbuckles, serial casting and static progressive splints. Additional information was accumulated from independent therapists for fifty (50) SPS knee, wrist, and elbow patients. SPS/Stress Relaxation therapy followed an established protocol for time published in Clinical Orthopaedics, June 1994, Vol. 303, P 128 and Physical Therapy, February 1996, Vol. 76, No. 2, P 182. A new device from Joint Active Systems (Effingham, IL) incorporates the principles of SPS and Stress Relaxation. This device is used by the patient both in the clinic and home setting and simulates some of the manual therapy techniques clinicians use when attempting to re-establish ROM (Fig.14).

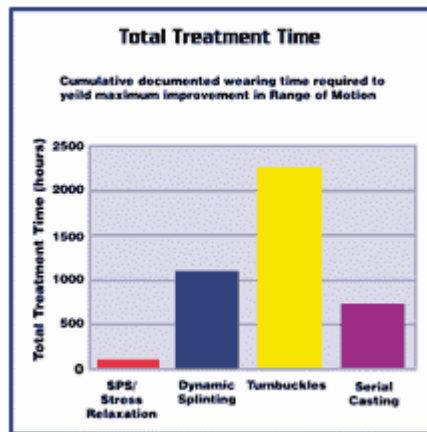
**FIGURE 14: JOINT ACTIVE SYSTEMS  
SPS/STRESS RELAXATION ORTHOSIS**



# RESULTS

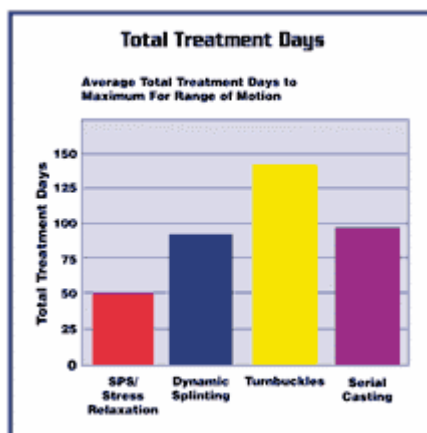
Dramatic variations in Total Treatment Time (TTT) and Treatment Days (TD), along with permanent gains in ROM were observed. The average TTT per direction was 2240 hours for turnbuckles, 1025 hours for dynamic splints, 712 hours for serial casting and 66 hours for SPS/Stress Relaxation (Fig. 15).

**FIGURE 15:**



TTT for the prescribed SPS/Stress Relaxation approach was up to thirty-four (34) times shorter than other methods evaluated here. Similar results were noted when comparing modalities by Treatment Days (TD). Variations of TD ranged up to 286% from averages of 140 days for turnbuckles, 91 days for dynamic splints, to 49 days for SPS/Stress Relaxation (Fig. 16). Based on the results, the principle of SPS/Stress Relaxation is ten (10) times more efficient than serial casting, eighteen (18) times more efficient than dynamic splinting and thirty (30) times more efficient that using a turnbuckle.

**FIGURE 16:**



The information gathered from independent therapists indicated that ROM gained with the SPS/Stress Relaxation approach was maintained at a one-year follow-up. Patient compliance was found to be a problem with all modalities. However, it was minimized with the SPS/Stress Relaxation protocol (compliance averaged 90%). The SPS Stress Relaxation device used in this investigation was patient directed. The patient was in control of the amount of force applied to the tissue. This helped increase compliance, as the patient was more relaxed while wearing the device.

## **CONCLUSIONS**

1. Tissue behaves in a viscoelastic manner when subject to loading conditions.
2. Using SPS/Stress Relaxation principles is the most efficient means of achieving permanent elongation of soft tissue.
3. Incorporating SPS and Stress Relaxation allows the tissue to reach a more ductile state faster than when Creep is employed.
4. Total Treatment Time (TTT) and Treatment Days (TD) were excellent measures of the efficiencies of the management of soft tissue and ROM limitations.
5. Average TTT varied by a factor of 34 among of techniques evaluated in this study.
6. TD varied by as much as 286%.v
7. Problems with tissue irritation, skin breakdown, joint pain and loss of motion in the contralateral direction were not prevalent with the SPS/Stress Relaxation protocol.
8. Compliance improves when the patient controls the force applied to the involved tissues

Patients treated following the SPS/Stress Relaxation principle returned to their normal functions and work in a shorter period or time. They were discharged from treatment earlier than those treated with other modalities and presented with no loss of ROM at one year follow-up. This represents a huge potential cost savings to the insurance companies and a reduced financial burden to employers. The difference in TTT and TD in the modalities compared merits further study. Effect on soft tissue and ROM limitations, as well as potential cost effectiveness in a rehabilitation program, are areas that also require further investigation.