Splinting Proximal Interphalangeal Joint Flexion Contractures: A New Design

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Proximal interphalangeal joint flexion contracture is a common and persistent problem in hand rehabilitation. This article discusses the advantages and disadvantages of several current splint designs for correcting this contracture and introduces an alternate design that uses wire in a 3-point pressure system. The advantages of this design include ease of fabrication, patient appeal, and effectiveness.

Flexion contracture of the proximal interphalangeal (PIP) joint presents one of the most common and persistent problems resulting from trauma to the hand or as a sequela of disease or central nervous system (CNS) dysfunction. A contracture can occur due to shortening or adherence of soft tissue structures surrounding the joint, including joint capsule, volar plate, ligament, tendon, and skin, or it can occur secondary to pathology within the joint itself as in arthritis. Accepted treatment modalities for joint contractures include heat, soft tissue massage, gentle passive range of motion, joint mobilization, active range of motion, and active use of the hand in selected therapeutic activities and activities of daily living (1-3). In addition, based on the principle that prolonged gentle stretch can cause shortened tissues to lengthen, a well-designed and properly fitted splint that holds soft tissue on stretch for many hours each day is an essential treatment method (4).

Many splints have been described for correction of PIP joint flexion contracture, including serial plaster cylinder casts (5), dynamic PIP extension splints (6, 7), and a spring wire 3-point extension splint with a coil at the PIP joint (1, 8, 9). The problem has also given rise to the production of several commercial designs, including the safety pin splint originally designed by Bunnell (10), the Caper™ safety pin splint, the LMB™ wire foam splint, and the Joint Jack™. The purpose of this article is to briefly discuss the pros and cons of those designs and to present an alternate design, specifically a 3-point proximal interphalangeal joint extension splint fabricated from aluminum wire or brass welding rod.

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The terms "springy" and "non-springy" have been used by clinicians to describe the end feel (i.e., the feel of the soft tissue when the joint is gently passively stretched to its maximum range) of a stiff joint. End feel will influence the choice of splint design and the prognosis for improvement by splinting.

In the discussion that follows, a springy end feel is defined as a condition that exists when a joint that is held at its maximum range of motion has an elastic quality so that if a slightly greater stretch is applied the joint responds with an increase in range of motion. A non-springy end feel exists when a joint that is held at its maximum range of motion has a nonelastic quality so that when a slightly greater stretch is applied the joint does not respond with an increase in range of motion.

Indications and Characteristics of Current Splinting Designs

Of the previously mentioned custom splints, we have used serial cylinder casts, dorsal hand-based dynamic PIP joint extension splints, and the spring wire PIP joint extension splint in our daily treatment. We have found that each design is superior to the others under certain circumstances.

Cylinder Casts

In our experience, cylinder casting is more effective than other splinting approaches when all of the following conditions are met: (a) the contracture has a non-springy end feel; (b) the contracture is greater than 45°; (c) the required immobilization of the PIP joint between cast changes is not contraindicated (as it would be, for example, after recent tendon repair or tenolysis); and (d) the patient is available for twice-weekly or more frequent cast changes.

Certainly, serial cylinder casts can be used in the presence of a springy contracture and/or if the contracture is less than 45°. However, other splints can be used with equal effectiveness under these conditions and would have the added advantage of being removable for active use of the impaired digit. Although cylinder casts can be made removable (5), we have found that nonspringy joints respond best if they are held on stretch full time between cast changes.

The advantages of serial casting include ease of fabrication, low cost of materials, and the unobtrusive design that allows complete motion at adjacent joints. Disadvantages include the necessity of frequent changes of the cast as the joint improves and immobilization of the PIP joint while the cast is in place.

Hand-Based Dynamic PIP Joint Extension Splints

Hand-based dynamic PIP joint extension splints are most effective when (a) the contracture is of any degree and has a springy end feel (for contractures greater than 90°, however, the awkwardness of the outrigger system would in most cases make application of a cylinder cast more acceptable to the patient); (b) tendon gliding is essential at frequent intervals during the day, as after tendon repair or tenolysis; (c) the advantage of strengthening offered by motion against the rubber band is desirable; and (d) time out of the splint is desirable for passive and active range of motion, strengthening exercises, and active use of the hand.

An advantage to the dynamic splint is that it can be used throughout the course of treatment of the stiff joint, with periodic adjustments of the outrigger by the therapist. In addition, if the splint base is applied to the dorsum of the hand, the impaired finger can be incorporated into activities of daily living while the splint is in place. The disadvantage of a dynamic splint is that its requirements for a stable base and point of attachment of the outrigger, whether of high- or low-profile design, make it more cumbersome on the hand and, therefore, less acceptable to the patient than a simpler splint.

Spring Wire Splint

Correction of a PIP joint flexion contracture by the use of a coil spring wire 3-point extension splint can be achieved by using a design described by Wynn Parry (1) and modified and popularized by Colitz (8, 9). The splint is finger based and can easily be removed by the patient. It has a trim line that enables the hand to continue to be used in activities of daily living. Colitz notes that the spring wire splint becomes less effective in joints with a contracture greater than 45° because the lever arms are not in a mechanically efficient position at a joint angle greater than 45° (8).

The advantages of the spring wire splint include comfort, appearance, and the minimally fatiguing force offered by the coil as compared to the fatiguing force offered by a rubber band in a dynamic splint. The coil provides a rotational force against the resistance of the contracted tissue, which is quite appropriate for the purpose of achieving motion about the joint axis. The disadvantage to this splint, in our experience, is that the flexibility of the spring wire is such that it may not be strong enough to overcome a "strong"
contracture—that is, one that has little or no spring to its end feel. Therefore, we have reserved the spring wire splint strictly for flexion contractures that are springy and measure 40° to 45° or less. Other disadvantages include the time required for fabrication by those who are not experienced with spring wire and the requirement of a jig for fabrication of the coils.

**Commercial Splints**

We have found that commercial splints are rarely the optimal choice to correct a flexion contracture. They lack custom fit and tend to be limited in the range of tension that they can apply to a stiff joint. In addition, the distribution of pressure by a commercial splint tends to be over a smaller area than the distribution of pressure by a custom-made splint because the commercial splint is not individually fitted to the curve of the phalanges. Therefore, pressure areas are a more frequent problem with a commercial splint than with a well-fitted custom splint.

A commercial design might be indicated if it provides a perfect fit to the involved digit and if the force it applies to the contracted tissue is appropriate to the circulatory status and overall condition of the soft tissues. If these criteria are met without compromise, then the advantage of time saved by using a commercial design is significant.

**Rationale for a New Design**

The splint design described below arose from a desire for a splint with some of the advantages of a cylinder cast and some of the advantages of a spring wire splint. Thus, the 3-point extension splint (see Figures 1–3) meets the following criteria:

1. It is effective for nonspringy and springy joint contractures of approximately 45° or less;
2. It is individually fitted to distribute pressure over as wide an area of the finger as possible;
3. It is based on the finger and can easily be removed several times a day to allow the patient to carry out other parts of the treatment program;
4. It has a streamlined design acceptable to the patient;
5. It is easily fabricated using wire that is strong but easily worked;
6. Like a cylinder cast, it provides a nongiving, nonelastic, gentle force against the resistance of contracted tissues;
7. The patient can adjust the amount of tension as instructed by the therapist; and
8. Because of its low tension, it can be worn for long periods of the day, thereby conforming to the principle of gentle prolonged stretch to elongate contracted tissues.

**Clinical Application of the 3-Point PIP Joint Extension Splint**

The 3-point PIP joint extension splint has been used in our therapy department for the past 5 years. Out of a patient population of 100 per week, approximately 10 to 15 individuals require fabrication of this splint as part of their overall therapy program. Their diagnoses include fractures, joint dislocations, and soft tissue injuries. For any injury, the therapist must consider the stage of healing of the injured structures and should consult with the surgeon before applying this splint. As a general guideline, however, this splint might be initiated at 4–6 weeks post fracture or joint dislocation, at 6 weeks post volar plate or collateral ligament repair, at 6 weeks post flexor tendon laceration in Zone II, and at 6 weeks post traumatic boutonnière. This splint is less frequently indicated for joint stiffness in chronic conditions such as central nervous system dysfunction, peripheral nerve lesions, and arthritis, be-
cause these conditions usually result in multiple joint involvement and/or muscle imbalance.

The amount of improvement in joint range of motion will depend on three factors. First, the splint must fit properly and must be applied properly by the patient. The second factor is the amount of time the splint is worn: The longer the joint is held on gentle stretch, the more effective the splint. The wearing schedule of this splint varies with each patient. It may be prescribed for two or three 1- or 2-hour periods a day, all night, or all of the time except for exercise and hygiene requirements, depending on other components of the therapy program. The third factor is whether the impaired joint is springy or nonspringy; springy joints respond more quickly. The therapist should reassess these factors at each patient visit to determine if adjustments in the splinting program are required.

We have observed in our patient population that springy PIP joint contractures usually show an improvement of 10–15 degrees of passive extension within the first week of splint wear. Nonspringy PIP joint contractures respond more slowly, with an average gain of only 5–10 degrees during the first week. Whether the joint is springy or nonspringy, the rate of improvement after the first week will vary, but the therapist can usually expect at least 5 degrees of increased extension per week. If progress levels off for more than 2 weeks, the therapist should consider an alternate splint design, such as cylinder casting.

Fabricating the 3-Point PIP Joint Extension Splint

The following materials are required for fabrication: 12" length of 3/8" brass welding rod (available from local welding suppliers); 1" wide filament tape; 4" x 4" piece of moleskin; 2" length of 1/2" wide adhesive hook Velcro®; and 4" length of 3/8" wide Velcro® loop, Velfoam®, or Betapile®. The tools needed are needle-nose pliers, felt-tip pen, scissors, and end wire nippers.

The components of the splint are identified in Figure 4. Several of the steps described below are based on steps in the fabrication of a spring wire splint as described by Colditz (8).

1. Use pliers to form the wire into a "U." Place the wire so that the curved end lies just distal to the distal palmar crease to allow flexion of the MP joint and the side bars lie along either side of the MP joint. For the index and small fingers, it is sometimes desirable to place the wire slightly proximal to the distal palmar crease to provide for a longer and, therefore, more stable palmar base. The width of the "U" must allow for the width of the finger plus 3/8" clearance on either side of the finger. The side bars must not impinge on the lateral aspects of the finger where they could cause pressure on the neurovascular bundles. Make sure the wire can lie flat on the table and the two side bars of the "U" are parallel to each other before proceeding to the next step.

2. Use a felt-tip pen to mark both side bars of the "U" approximately 1/4" distal to the web on either side of the finger, taking into account differences in the level of the web spaces on either side of the finger. Bend the wire at the marked point on both side bars at a 70° angle (see Figure 5). The 70° angle allows the side bar(s) to travel to the dorsum of the finger without impinging on the skin web(s).

3. With the wire in place on the finger and the metacarpophalangeal (MP) joint held in extension, mark both side bars at the midlateral line of the proximal phalanx. Bend each side bar of the "U" at a 70° angle so that it will lie along the midlateral line of the proximal phalanx (see Figure 6).

4. With the wire in place on the...
finger and the MP joint held in extension, mark both side bars at the axis of the PIP joint. *(Note: The PIP joint axis is located where the PIP flexion crease intersects the midlateral line of the finger.)* Bend the wire at the axis at an angle 10–15° less than the angle of flexion-contracture of the joint (see Figure 7). *(Note: The wire is bent at an angle less than the angle of contraction so that when the tension strap is adjusted, the finger can be lifted toward the angle of the side bars.)*

5. Pad the palmar base of the splint with 6 to 8 overlapping layers of filament tape trimmed to conform to the “U”-shaped palmar base. Add an outer layer of moleskin and trim this also.

6. The saddle is formed using a length of filament tape and a 4” x 4” piece of moleskin. Begin by placing the adherent side of the filament tape on the inside of one side bar at the level of the proximal phalanx. Adhere the tape to itself around the outside of the same side bar. Now place the splint on the finger so that the smooth side of the tape lies across the dorsal lateral surface of the proximal phalanx and on the inside of the opposite side bar. Wrap the tape around the side bar to the outside of the splint then back on itself to complete this portion of the saddle. The curvature and height of the saddle should be such that the splint is not pulled out of its position along the midline of the proximal phalanx (Figure 8).

Pad the saddle by enclosing the tape within a single piece of moleskin. The moleskin should be applied so that a seamless surface lies over the dorsal-lateral skin of the proximal phalanx and the edges of moleskin all lie on top of the saddle (see Figure 9). If the saddle is not fitted correctly, it will have a tendency to cause pressure at the distal end of the proximal phalanx when tension is later applied by the strap.

7. Mark both side bars of the splint approximately ¼” distal to the distal interphalangeal joint crease. Hold the pliers at the marked point and use a second set of pliers to bend the distal portion of the side bar into a tight curl around the tip of the first pliers. Then cut off the excess wire with end nippers and close the curl with pliers so that there are no sharp edges protruding from the splint.

8. The tension strap is fabricated from a 4” length of a ½” wide piece of Velcro loop and a 2” length of a ½” wide piece of adhesive Velcro hook. Apply the adhesive Velcro hook to one side bar at the level of the DIP joint crease and adhere it to itself. With the splint in place on the finger, apply the strip of loop Velcro to the top side of the hook Velcro. Adjust the amount of tension applied by the strap by bringing the loop Velcro under the finger, over the opposite side bar, and then back to the underside of the hook Velcro (see Figure 10).

If the tension strap is placed distal to the DIP flexion crease, hyperextension of the DIP joint may result instead of extension of the PIP joint. The tension applied by the strap should be such that the patient is able to perceive a slight pull on the PIP joint to bring it into extension.

9. After the patient wears the splint for 30 minutes, remove it and check for pressure areas. If red marks are noted over the distal
portion of the proximal phalanx, the saddle may have been fitted too snugly. Remove the saddle and fabricate a new one. If skin blanching is noted, the amount of force applied by the tension strap should be decreased.

10. Teach the patient to apply the splint and be sure that he or she understands this well.

11. As the PIP joint flexion contracture improves, the angle of the side bars at the joint axis must be adjusted so that they continue to be 10–15° less than the angle of the flexion contracture. As the joint approaches 0°, the angle of the side bars will be in slight "hyperextension" relative to the PIP joint.

Summary

Current approaches to splinting PIP joint flexion contractures have been briefly discussed to point out some of the advantages and disadvantages of each approach and the need for proper selection of design depending on the nature of the joint contracture. In addition, a custom-fabricated 3-point PIP extension splint was described. Because of its ease of fabrication, patient appeal, and clinical effectiveness, this custom design provides an attractive alternative to other designs when the joint contracture is approximately 45° or less and when the joint end feel is springy or non-springy.

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REFERENCES