A Belly Gutter Splint for Proximal Interphalangeal Joint Flexion Contracture

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Key Words: contracture • splints

Various splints are available for the correction of proximal interphalangeal (PIP) joint flexion contracture in patients with hand injuries. This article discusses the mechanics of several splints. The belly gutter splint, an alternative design that can be used for this contracture, is introduced.

Flexion contracture of the proximal interphalangeal (PIP) joint occurs frequently after a hand injury. The contracture may be due to direct trauma to structures of the PIP joint (Weeks & Wray, 1973), to edema and immobilization (Boyes, 1970), to incorrect early positioning (Watson, 1982), or to inappropriate finger extension exercises (Wilson & Carter, 1984; Wu, 1986).

Splinting has been an effective modality in the reduction of PIP joint flexion contracture. The various splint designs for this problem include the dynamic PIP extension splint (Fess, Gettle, & Strickland, 1981; Malick, 1974), the reverse knuckle bender (Boyes, 1970), the Capener splint (Capener, 1967), the spring-wire splint (Colditz, 1984), the LMB Wire-foam[1] splint (American Academy of Orthopaedic Surgeons, 1985), the safety pin splint (Boyes, 1970), and the Joint Jack[2] splint (Watson, 1982).

Dynamic, or elastic, splints with rubber-band or coil-spring elements may be less effective clinically than static, or inelastic, splints for severe flexion contracture of the PIP joint. Watson (1982) stated, "Correction force for contracture of hand joints should usually be steady and inelastic. Elastic or spring splints produce a steady one-way force only when the patient is asleep or so relaxed that the opposing muscles are not periodically reducing the effectiveness of the elastic force" (p. 453). Furthermore, a dynamic PIP extension splint may be less acceptable to the patient because of the awkwardness of the outrigger system. Although both the Joint Jack splint and the safety pin splint apply steady and inelastic tension, they are less effective if the flexion contracture of the PIP joint is greater than 35° (Boscheinen-Morrin, Davey, & Conolly, 1985; Fess et al., 1981). This is because the traction tensions from the proximal and distal ends of the splint are not applied at a right angle to the phalanx (Fess et al., 1981).

The belly gutter splint, which is a modification of the finger gutter splint, is offered as an alternative design. The advantages of the belly gutter splint are that it (a) provides steady traction force; (b) has no outrigger; (c) provides traction force at a right angle to the phalanx; (d) is custom-made and, thus, is applicable to any angle of flexion contracture; (e) is easy to make and modify; and (f) is clinically effective.

Mechanics of Splints for PIP Joint Flexion Contracture

Splints for the correction of PIP joint flexion contracture can be categorized into two groups, depending on whether the traction characteristic is elastic or inelastic. Elastic, or dynamic, splints use an elastic element, such as a rub-

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[1]Available from LMB Hand Rehab Products, Inc., PO Box 1181, San Luis Obispo, CA 93406.

[2]Available from Joint Jack Company, 135 Addison Road, Glastonbury, CT 06033.

ber band or coil spring, as a traction force. Inelastic, or static, splints usually use an inelastic strap for traction.

The mechanical principles differ for each group of splints. The dynamic splint has fixation proximally and traction distally (i.e., fixation-traction principle). For example, with a dynamic splint, the proximal phalanx is fixed firmly and the middle phalanx is movable for application of the traction force. In spring-wire splints, the two pressure points proximal to the PIP joint work together to provide synergic fixation; the third pressure point distal to the PIP joint provides the traction force. A dynamic PIP extension splint uses a lumbrical bar and the splint base for proximal fixation and rubber bands attached to an outrigger for distal traction force (see Figure 1).

Static splints (e.g., Joint Jack, safety pin, belly gutter) use the three-point-pressure principle—two points on the volar side of the phalanxes and one point on the dorsal side of the PIP joint. When a static splint is applied, pressure on the dorsal side of the PIP joint and two pressures points on the volar side of the phalanxes are exerted to hold the parts in an extended stressed position (see Figure 2). Both the proximal and middle phalanxes, therefore, will be mobilized by a steady three-point-extension moment arm on a joint with those splints. Joint Jack and safety pin splints apply two points of volar pressure in the same plane so as to make a perpendicular pull on segments impossible if flexion contracture is greater than 35°. Conversely, the belly gutter splint provides traction tension at a 90° angle to the phalanx by incorporating a convex belly in the middle of the gutter, with the bottom of the gutter at either end of the belly parallel to the phalanx. In this design, the direction of force through the slope of the convex belly is perpendicular to the phalanx (see Figure 3).

In physics terms, dynamic and static splints are second-class levers, because the resistance is between the axis (fulcrum) and the force. Because the belly gutter splint provides two extension moments, the magnitude

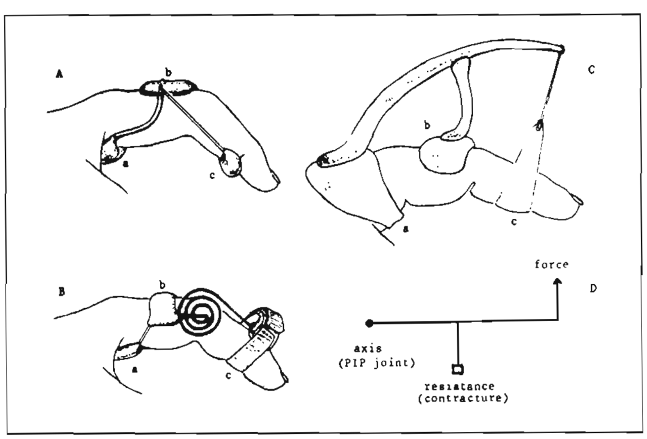

Figure 1. Elastic splints: (A) the LMB Wire-foam splint, (B) the Capener splint, and (C) the dynamic proximal interphalangeal (PIP) joint splint. (D) illustrates the leverage of elastic splints.

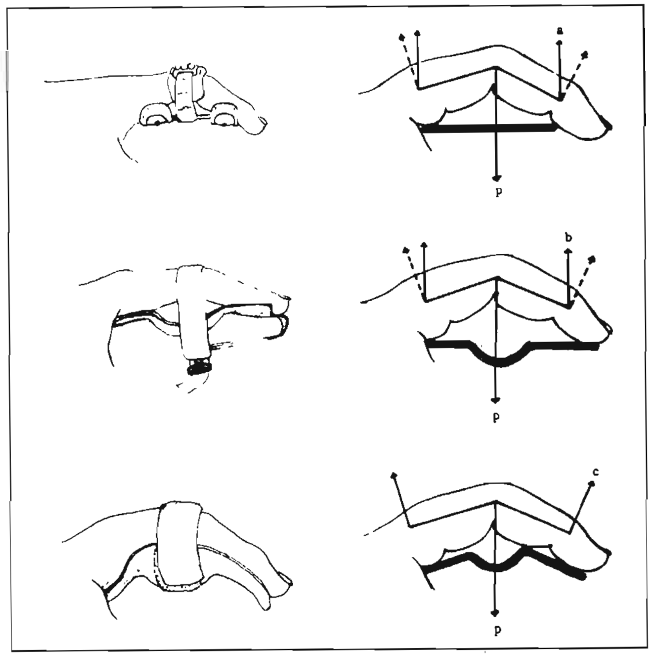

Figure 2. Inelastic splints: the safety pin splint (top), the Joint Jack splint (middle), the belly gutter splint (bottom). *Note.* Pictured to the right of each splint is a mechanical analysis. Dashed arrow = perpendicular pull on the segment; solid upward arrow = pressure on the volar side of the phalanx; solid downward arrow = pressure on the dorsal side of the proximal interphalangeal joint.

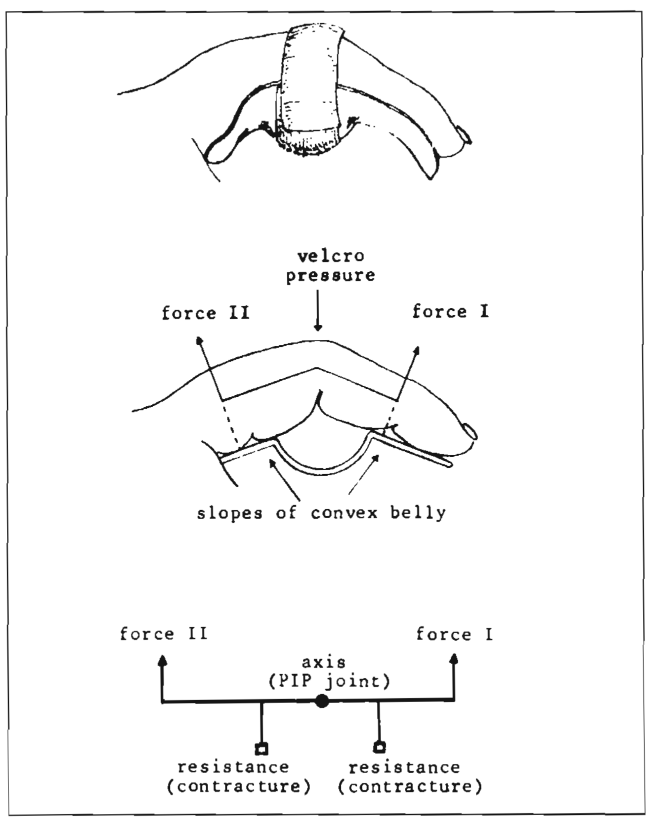

Figure 3. The belly gutter splint (top), a mechanical analysis (middle), and leverage (bottom).

of the traction forces applied to the contracture tissues is greater than that applied by an elastic, or dynamic, splint (see Figures 1 and 3).

Fabrication of the Belly Gutter Splint

Materials needed for the belly gutter splint are a low-temperature thermoplastic material, 1-in. (2.54 cm) adhesive-hook touch fastener, 1-in. (2.54 cm) loop touch fastener, and adhesive cushioning.

To make the belly gutter splint, cut a piece of splinting material equal to the length of the finger from the metacarpophalangeal flexion crease to the tip of the finger and the width of the finger plus 2 cm. Place this piece under the patient's finger and, with a ballpoint pen, mark the axis of both the PIP joint and the web of the finger.

After heating the material to make it malleable, shape a convex belly in the area between the two marked points. Then draw a U pattern from the proximal edge of the splint to the two points marked for the web. Cut out the portion on either side of the U pattern (see Figure 4). Form the portion distal to the web into a U, allowing for 1 mm of clearance on either side of the finger (see Figure 5).

Place the gutter on the volar side of the finger with the center of the convex belly facing the axis of the PIP joint. Place the bottom of the gutter distal to the belly to accommodate the volar surface of the middle and distal phalanxes. Trim the splint edge so that the height on either side of the gutter is no higher than 1 cm and so that the edge slopes down at the distal interphalangeal joint (see Figure 6). With the gutter placed on the finger, trim the end that is distal to the fingertip. Round and then flange the distal end away from the finger to avoid pressure to the fingertip.

Check the fit. There should be sufficient clearance of the web space and no hyperextension of the distal interphalangeal joint. With the gutter in place on the finger, mark either edge at the axis of the PIP joint. Apply the hook touch fastener to the convex belly with the middle of the width of the hook touch fastener just corresponding to the point marked for the axis of the PIP joint. Using scissors, make a notch on either side of the hook touch fastener at the top of the convex belly and press it down

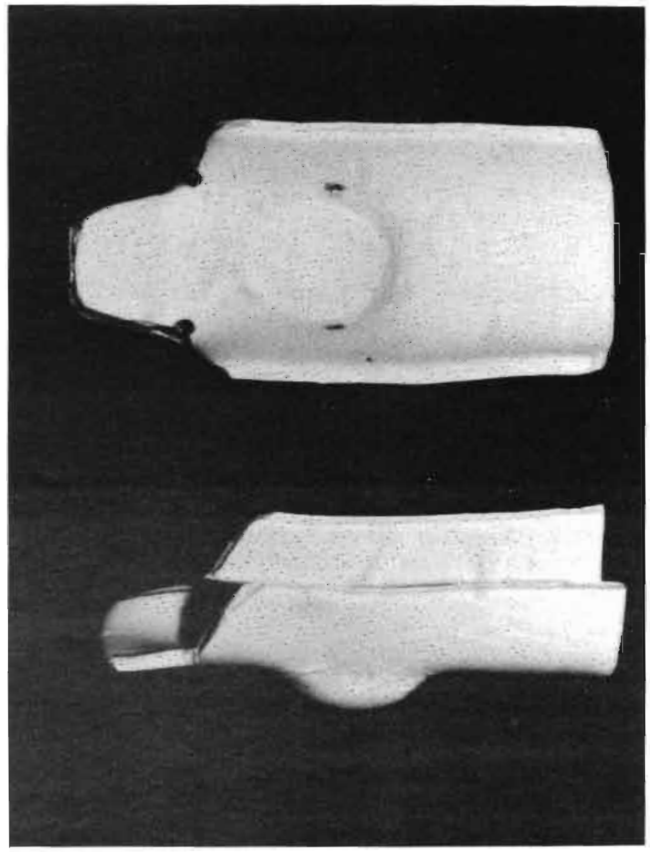

Figure 5. Making the portion distal to the palmar base into a U form, as seen from a dorsal (top) and lateral (bottom) view.

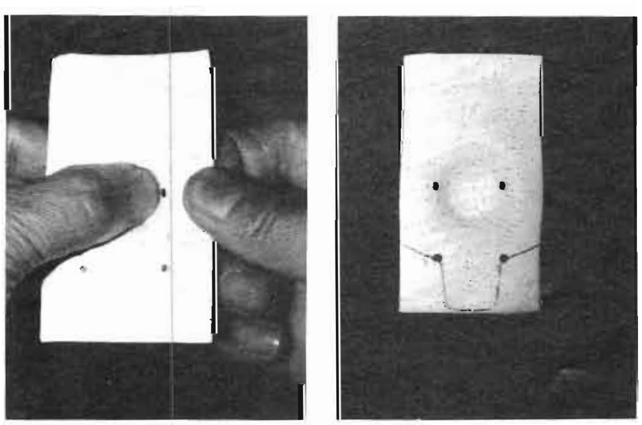

Figure 4. Shaping a convex belly (left) and drawing a U pattern (right) as part of the fabrication of a belly gutter splint.

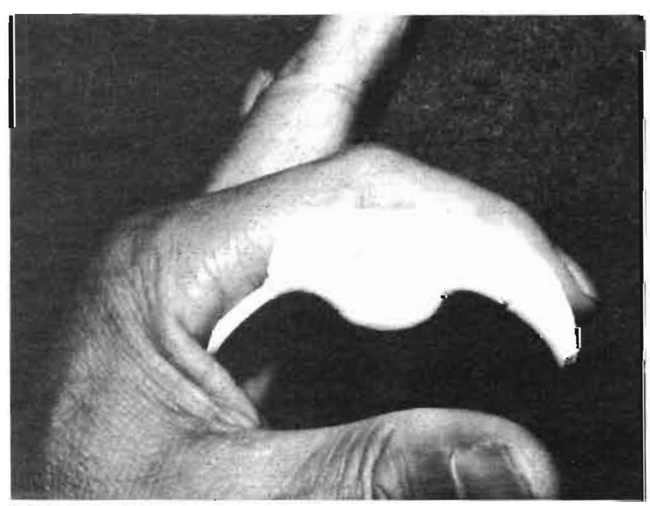

Figure 6. The gutter edge of the belly gutter splint is trimmed off.

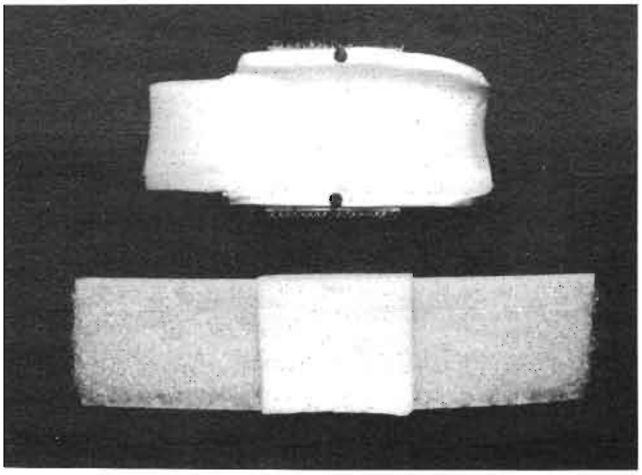

Figure 7. Padding is anchored to the palmar base of the gutter (top) and the middle (bottom) of the loop touch fastener.

to the surface of the belly so that it adheres completely to the convex surface.

With the gutter in place on the finger, place a strip of loop touch fastener, long enough to lie across the dorsal surface of the PIP joint, onto the hook touch fastener. This strip will serve as the tension strap to provide the forces for correction of the PIP joint.

Apply adhesive cushioning on the palmar base of the gutter splint and on the middle of the strip of loop touch fastener to serve as a pad (see Figure 7).

Application and Results

Teach the patient how to apply the belly gutter splint and provide a wearing schedule. For the first week, the splint should be worn daily for 20-min periods separated by short intervals. After that, the splint should be worn daily in 1- or 2-hr periods separated by short intervals. As joint extension improves, the splint may be worn at night and during rest or when the hand is not being used.

As the contracture improves or if the patient does not feel the PIP joint pulling into extension when wearing the splint, soften the thermoplastic material distal to the belly and adjust it to accommodate the volar surface of the middle and distal phalanxes. Be aware that excessive pressure of the touch-fastener traction on the dorsum of the PIP joint will cause skin damage.

Our department has used the belly gutter splint for more than 3 years. In this time, we used this splint to treat 32 fingers of 23 patients (18 men and 5 women) to correct PIP joint flexion contractures. Of these 32 fingers, the diagnoses were as follows: metacarpal fracture (9), proximal phalangeal fracture (10), middle phalangeal fracture (2), proximal and middle phalangeal fracture (1), dislocation of the PIP joint (2), and replantation (8). The length of time for achievement of a passive range of 0° after

Table 1
Results of Belly Gutter Splint in Proximal Interphalangeal (PIP) Joint Flexion Contracture by Hand Injury Diagnoses

Diagnosis	Weeks of Splint Application After Operation	Weeks of Passive Range of 0° After Splinting	No. of Fingers
Metacarpal fracture	7	1	1
	9	1	1
	9	2	3
	14	1	1
	14	4	3
Proximal phalangeal fracture	5	1	1
	5	6	2
	7	10	1
	7	12	1
	7	16	1
	11	1	1
	14	12	2
	15	7	1
Middle phalangeal fracture	7	1	1
	11	1	1
Proximal and middle phalangeal fracture	5	12	1
PIP joint dislocation	4	6	1
	7	1	1
Replantation (level: proximal phalanx)	6	8	1
	9	8	1
	12	2	3
	14	3	1
	15	1	1
	22	5	1

splinting was irregular (see Table 1). Generally, resolution of flexion contracture varied with the patient's age, the length of time since injury, the site of injury and the anatomical structures involved, the length of time in the splint, and the patient's motivation and cooperation. Clinical observations have revealed that the patient's cooperation may be the primary factor affecting the amount of time needed to achieve positive results. ▲

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