Principles of Splinting and Splint Prescription

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Choosing Splints Based on Biologic Stages of Healing
- Stage I: Inflammation
- Stage II: Fibroplasia
- Stage III: Scar Mobilization

Biomechanics of Splinting
- First Class Levers
- Mechanical Effectiveness
- Even Distribution of Pressure
- Prolonged Tension
- Easy Adjustment
- Biomechanical Forces

Splints for Clinical Problems
- Splints for Joint Stability
  - Splints to Reduce Joint Tightness
  - Proximal Interphalangeal Joint
  - Metacarpophalangeal Joint
  - Wrist Joints
- Splints to Reduce Muscle-Tendon Tension and Adherence
  - Intrinsic Muscle Tightness
  - Extrinsic Muscle Tightness
- Splints for Nerve Injuries
  - Median Nerve Palsy
  - Ulnar Nerve Palsy
  - Radial Nerve Palsy
- Splints for Tendon Injuries
  - Flexor Tendons
  - Extensor Tendons
- Splints for Scar Skin Tightness
- Splints for Fractures and Joint Dislocations

History
- Hand Surgery
- Manufactured Splints
- Hand Therapy and Low Temperature Plastics

Splinting Terminology

Principles and Goals of Splinting
- Immobilization Splints
  - Reduction of Inflammation from Trauma
  - Reduction of Inflammation from Arthritis
  - Control of Pain
  - Prevention of External Support
  - Substitution for Absent, Weak, or Unbalanced Muscles
  - Evaluation of the Potential for Surgery
- Mobilizing Splints
  - Protection of Healing Structures
  - Increase or Maintenance of Joint Motion and Soft Tissue Glide
- Influence on Skin Scar Formation

Categories of Splints Which Immobilize and Mobilize
- Static
- Dynamic
- Serial Static
- Static Progressive
- Continuous Passive Motion

Information Necessary for Hand Splinting
- Splint Position and Architecture of the Hand
- Kinesiology of the Hand
- Surgical Procedures

Basic Science
- Pathology of Stiffness
- Human Tissue Response to Stress

2389
Sutures for Cutaneous Deformities
Sutures for Dupuytren’s Contracture Release
Sutures for Rheumatoid Arthritis
- Nonoperative
- Postoperative

Suture Preservation
- Current Issues
- ASHT Suture Preservation Recommendations

Complications
- Inadequacy
- Inefficacy

Unsolved Issues

HISTORY
For centuries physicians have used suture and homemade devices to immobilize and support injured limbs. Before modern health speciﬁcation, the physician of surgery had the devices or enlisted the help of the local blacksmith or carpenter. It is only in recent years that hand splinting has become part of a trained discipline.

The many efforts from the first and second world wars and the large number of polio patients stimulated the development of orthotics and prosthesis in the early 20th century. The large number of patients needing splinting must have inﬂuenced Bunnell’s statement: “Sutures should be standardized as much as possible to facilitate the large volume of work done by many people.” Polio was a signiﬁcant catalyst for developing standard orthotic designs.

Hand Surgery
Bunnell and the other pioneers of hand surgery clearly recognized that static splints were needed for correct positioning of the hand postoperatively. Dynamic or spring splints were recommended to mobilize stiff joints. The ﬁrst splint was important because of the long transportation time for injured soldiers who were initially treated in ﬁeld hospitals and then transferred state-side for deﬁnitive surgical care. Many of these hands were debilitated owing to incorrect initial splint immobilization.

Although Adams, Koch, Koch and Masen, Neviaser, Marple, Oppenheimer, and others1,2,4,5 from the 1920s to the 1940s published descriptive articles about speciﬁc splints, it was Bunnell in his Surgery of the Hand in 1944 who provided the ﬁrst extensive review of hand splinting for the surgical patient. Most other publications from that time were anecdotal description of favored designs with few or no references.3,6,8

In the fall of 1944, just as Bunnell’s book was published, he was asked by the U.S. Surgeon General to be the civilian consultant to the eight general hospitals in the Interior Zone.1 In the following 25 years when he traveled to these ﬁve hand centers, his teaching about the need for initial splinting to immobilize and dynamic splinting to remobilize the hand became the standard of care.

Manufactured Splints
Many manufactured splints have been used such as Bunnell’s knuckle hanger splint, Oppenheimer’s splint,2 and the Thomas suspension splint2. When manufactured splints were not available, dynamic splints were built using plaster of paris with wire outriggers incorporated into the plaster base as described later by Peacock.4 Many of these classic designs continue to be referred to frequently. Numerous splints of this period were constructed by orthotists or orthopaedic technicians whose materials were limited to plaster, metal, wire, felt, and leather1,5,6. A few high-temperature plastics were reserved for permanent disabilities (polio, spinal cord injuries, and extensive peripheral nerve loss).

Moberg observed that each U.S. hand surgeon had to have a splint workshop.22 Bunnell also had several ready-made splints from a surgical instrument supplier for rehabilitation of his patients.20

Hand Therapy and Low Temperature Plastics
In the 1960s and 1970s two concurrent events brought splinting into the mainstream of hand surgery practice. Hand therapy developed as a specialty, and low temperature thermoplastic splinting materials became readily available.

As physical and occupational therapists began working closely with hand surgeons, they developed and shared effective techniques of rehabilitation and splinting. Splinting was now an integral part of immediate postoperative care, in contrast to the days of polio when the orthotist, removed from the patient’s care, would independently construct a device.

Therapists developed an increasingly important role as the low temperature thermoplastics allowed splints to be molded directly on the patient, and easily modiﬁed as function progressed. The roles of the orthotist and therapist became better deﬁned: the orthotist made bracing for permanent loss, while the therapist was an active participant in the rehabilitation process. Early hand rehabilitation texts included chapters on splints.29-32 Commercially produced metal, felt, and wire splints fell out of favor because they were not as well tolerated as custom-designed and individually molded ones.

Now all surgeons work closely with experienced and trained therapists who can make splints. Many surgeons writing about

FIG. 111-1. Bunnell and others made dynamic splints of plaster of paris in which wire outriggers were incorporated. (From: Bunnell’s Surgery of the Hand, 4th ed. Philadelphia, JB Lippincott, 1964, with permission.)
Splinting illustrates the early win and fail designs.3,4 Therapists must agree whether the custom-made splints provide improved tolerance and better clinical results. There are no published clinical studies proving the advantage of custom splints.

Splinting Terminology
The art and craft of hand splinting are the responsibility of therapists. The absence of standardized training in splint making and the use of colloquial descriptive terms have prevented the recognition of hand splinting as a science.

What one person calls a "wrist cock-up splint," another calls a "wrist control splint," and yet another calls a "wrist support splint." This inconsistency terminology prevents easy communication and lacks a common language for comparative results. Moberg identified the need for better description and regulation of splinting.6 He recognized that splinting "encompasses a profusion of devices and terminology, and because similar splints may be used for dissimilar purposes, description and classification of various splints are often fraught with confusion, redundancy, and omission."35

In 1986, because of a member survey, the American Society of Hand Therapists (ASHHT) identified the need for standardized terminology. In 1992 it published the ASHHT Splint Classification System.20 Descriptions were based on the function of the splint rather than its form. This system uses a logical progression of descriptors so any splint for any joint can be accurately described (Fig. 111-2). It identifies which parts are included in the splint for primary mobilization, immobilization, or restriction and further describes the secondary parts included. With this system colloquial terms or regional descriptors are no longer used, but the purpose of the splint is the prime descriptor. The problem with this system is that one splint design may have many different functions (Fig. 111-3).

Transitions to the new nomenclature will require new generations to learn and use this system. This is a major challenge, since we all have the habit of envisioning a three-dimensional device when we describe a splint. The idea is for the surgeon to know the skills of the hand therapist. A referral regarding the function of the splint is transmitted, but the actual design is left to the therapist.

PRINCIPLES AND GOALS OF SPLINTING
Hand splinting can have one of two purposes: immobilization or mobilization.2 Both splinting functions have a crucial role in helping gain maximum function following trauma surgery. The challenge for therapists and surgeons is to decide when each type of splint is most useful. Streickland described the dilemma well: "A strong appreciation for the biologic state of the involved tissues will aid in making decisions as to whether the injured part should be managed by rest or stress and the best timing for the use of each type of splint."

Immobilization Splints
First, and most commonly, splints are used to immobilize and rest healing tissue.

Reduction of Inflammation from Trauma
Resting hand tissues reduces inflammation to encourage orderly healing without disruptive external influences and is the initial choice for the acutely injured part. The normal inflammatory response to trauma, infection, and pain will respond positively to rest. Bunnell was emphatic that such splinting should cease when possible because of the atrophy and stiffening which rapidly occurs in the immobilized hand.37 Immobilization periods have become shorter to minimize the negative effects of prolonged stiffness.

Reduction of inflammation from arthritis
Inflammatory arthritis responds to rest, but the rest may be short-lived, providing daily symptomatic relief. Splinting to provide rest, used with other treatments, has long been recognized as a standard protocol in this patient population.

Control of Pain
Without infection, rest of the acutely injured hand can decrease pain. In the healing hand, a delicate balance between rest to reduce painful inflammation, and exercise to maintain tissue guide can be accomplished by a removable splint.
Prevention of External Support

Splints may be used during any stage of healing to provide external support to intact structures. Unstable joints resulting from trauma or arthritis can benefit from such splinting for symptomatic relief and functional assistance (temporarily or as a substitution for surgery). Substitute for Absent, Weak, or Involuntary Muscles

Splints may also be useful when a major nerve injury depriving the hand of normal muscle balance. Although a splint cannot simulate the dynamic balance of muscles, it can provide a blocking or stabilizing force to prevent overriding of de-acquainted muscles and joint contractions.

Evaluation of the Potential for Surgery

Finally, it is selected cases, the temporary use of splints may help with surgical decisions. External splints applied to joints recommended for surgical fusion can assist the patient and surgeon in deciding the best position for arthrodesis. Surgical waiting can be minimized by external splinting to learn the functional advantages, or disadvantages, of such a procedure.

Modifying Splints

The second purpose of hand splinting is to modify tissues using force to apply a splint to aid the way tissue heals. The appropriate use of modifying splints may eliminate the need for a surgical procedure.35

Many mobilization splints have a movable component, which applies force to the joint or joints, of the hand and increases joint motion.

Protection of Healing Structures

Splints can provide defined limits to tissue glide as stress. "Controllable" motion has been shown to produce superior clinical results following flamed tendon repair and is an effective technique for unstable proximal interphalangeal (PIP) joint dislocations.36,37

Increase or Maintenance of Joint Motion and Soft Tissue Glide

Immobilization to protect healing structures can freeze joint motion, especially when20 edematous small joints are held in an unhealthy position. Tendons must glide through a scanted bed, and muscle re-stored normal elasticity to effect movement. Each use of dynamic splinting to help joints regain mobility is well recognized.38-40 The advantages of early motion have encouraged early rehabilitative splinting to maintain joint motion while protecting healing structures, such as flexor tendons.

Influence on Skin Scars Formation

All scar contracts via heals.19 In the hand this is of particular functional concern if skin covering joints becomes too short to allow normal motion. Prolonged positioning of the scar at maximum length combined with positive pressure19 to minimize scar hypertrophy can often prevent the need for surgical release.

Categories of Splints Which Immobilize and Mobilize

There are four types of splints: Static splints immobilize and do not provide mobilization. Serial static and static progressive splints hold tissue at maximum length and are changed periodically to encourage tissue to lengthen. These two types combine positive characteristics of both immobilization and mobilization splints. A fifth device which mobilizes tissues is a continuous passive motion machine (CPM), which will also be discussed.

Static: A static splint is a device molded or applied directly to the bone that maintains the hand or fingers in one position (Fig. 111-4). It may be worn continuously to support healing tissues or removed periodically to allow periods of specific protected exercises. Static splints are used most often to rest joints, provide external support, and in- tensively gain or maintain motion which has little resistance.
Dynamic

Dynamic splints provide a constant force to the joint(s). A dynamic splint has a base, usually made of molded plastic material, held securely to the hand and/or forearm. The force is generated either by a stretched rubber band or a wire spring coil via an outrigger attached to the base. The outrigger ensures that the force is directed at or close to a 90-degree angle to the long axis of the bone (Fig. 111.5). While the splint is worn by the patient, there is a constant force applied and, even as motion improves, the splint force continues. Dynamic splints are removable, and the force is intermittent because the splint is removed periodically.

Serial Static

Serial static splints are molded in a stationary position with the tissue at maximum length. They are changed frequently to accommodate the decreased resistance in the tissues. Such a splint may be a

FIG. 111-5. A dynamic splint extends the proximal metacarpal-phalangeal joint, while metacarpophalangeal joint extension is blocked by the outrigger of the splint. ASBTT splint classification: EP-SP TIP extension mobilization splint, MP flexion, type D8.
plaster cast17 worn continuously until removed by the therapist (Fig. 111-6) or a molded plastic splint applied and removed by the patient. The splint is worn for long periods so that the tissue adapts to this new position. Ideally the cast is changed every other day, or at least twice weekly, with brief periods of supervised exercise when out of the splint. For patients who live some distance away from the clinic, the logistics of these frequent visits can be difficult.

Plaster of Paris has long been recognized as an effective means of applying effective serial static splinting because of its conformability and the belief that inflatable splints are more effective.7,53 Many believe serial casting is indicated when use of dynamic splinting has failed.54 The author's experience supports the use of dynamic splints in joints responsive to manual stretch. For dynamic splinting to be effective, edema must be resolved and the injury must have been more.

Often the question is whether to splint for prolonged periods in one direction when the joint lacks motion in both directions. Bell-Krotoski believes serial casting for proximal interphalangeal joint contractions is underutilized because of a fear of flexion motion.2 Although flexion is decreased temporarily, positioning the joint in extension by tape elongates decreases the resistance to flexion.

Static Progressive

Static progressive splints may be identical with dynamic splints in construction of the splint base and outrigger, but the application of force is not dynamic. The force may be applied via the same outrigger and finger pop system or by another means. Instead of a rubber band or spring, tension is maintained one-tenth (commonly with Velcro or mechanical components which can be adjusted in small increments) (Fig. 111-7).

The theory of static progressive splinting (holding the joint at ease maximum available length) is the same as that for serial static splinting. The primary difference is the way in which forces are applied. When serial static casting is used, force is evenly distributed over all surfaces. Static progressive splinting concentrates the force through the surface area of the splint part applying the pressure. Although the force application should be small, the amount of applied tension is variable, owing to the patient's ability to adjust it.

FIG. 111-6. A cast is applied to the finger to gain proximal interphalangeal joint extension. ASIFT splint classification: PIP extension mobilization, type I (2).

Static progressive splinting allows the patient to engage the splint and work on active glide and other stretching, or use another splint.

Continuous Passive Motion

Any discussion of splints that help to regain joint motion is not complete without consideration of CPM machines. Saltz's work has shown the significant benefits of CPM for treatment of unstable fractures.55 The advantages of increased wound union strength from CPM application56 have led to its application in a variety of conditions.

The therapist may need to add a custom splint to block motion in nontal joints so that the motion of the CPM machine occurs at the involved joints (Fig. 111-8). CPM use is generally reserved for the early postoperative stage in order that山谷 value occur once the collagen fibers have developed cross-links and demonstrate resistance.

INFORMATION NECESSARY FOR HAND SPLINTING

The splint maker needs to understand the healing process and how splinting can affect it. A thorough knowledge of histomorphology, histology, pathology, and surgical procedures is also necessary.

Splint Position and Architecture of the Hand

Respect for the wrist as the keystone for hand positioning is the basis for all splinting, except isolated digital splinting (Fig. 1110). The weight of the immobile hand, gravity, and resting muscle tension tend to pull the wrist into flexion, which increases tension in the extrinsic extensor tendons, pulling the metacarpophalangeal joints into extension. Concurrently, the tension of the extrinsic flexors is maintained, forcing the interphalangeal joints into flexion. The transverse arch of the hand, created by the descending arc of the metacarpal heads (by CMC flexion), is also lost when the metacarpophalangeal joints are extended. Both the longitudinal and transverse arcs are thereby lost.

With flexion with increased extension tension inhibits the intrinsic-mediated metacarpophalangeal flexion and interphalangeal extension, resulting in the "intrinsic minus" position. The addition of edema sentences a hand immobilized in this position to months of
In passive rehabilitation to regain the normal balance of motion. (See Chaps. 68 and 69.)

Equally important as wrist extension is the maintenance of the thumb in its opposite position of abduction and pronation. Wrist flexion also exerts tension on the thumb extensors, pulling the thumb into adduction, which makes it difficult to recruit the (balancing) intrinsic muscles. The thumb web develops an adduction contracture, limiting functional opposition.

Historically authors have advocated two different, but similar, positions to prevent these deformities; the "safe or functional" position and the "intrinsic plus" ("clam digger") position. Before antibiotics and aseptic procedures, the likelihood of infection complicating any open injury or surgical procedure was significant. Therefore if the hand were to stiffen it was desirable for it to stiffen in such a position so as to still be useful. By positioning the wrist in slight (30 degrees) extension, the thumb in abduction, and all finger joints in slight flexion, the hand would likely retain some pinch ability even if stiffened by infection.

As surgical results improved, the intrinsic plus position was advocated because it favored the weaker intrinsic muscles of metacarpophalangeal and interphalangeal joints and finger flexion that are so difficult to obtain. The intrinsic plus position is not meant for

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**FIG. 111-9.** A Wrist extension positions the hand naturally into the normal transverse and longitudinal arches. B As the wrist falls into flexion, the tension of the extrinsic extensors causes both arches to be lost.

**FIG. 111-10.** A. The safe or functional splinting position places all joints in a meposition. B. The intrinsic plus position places the metacarpophalangeal (MCP) joint in maximum flexion and the interphalangeal joints in maximum extension with the thumb fully abduced.
prolonged immobilization and must be balanced with early motion and attention to intrinsic muscle stretching as healing allows. Neither of these is a “position of choice” for all injuries or procedures. The individual tissues injured dictate the mechanical design of an immobilization splint to optimize the result.

Kinesiology of the Hand

The splint maker can no longer have only a vague idea about kine- nology. New information about tendon excursion, joint kinematics, and muscle fiber length must be applied to splinting. The ther- apist must recognize patterns of pathological movement readily and appreciate how external splinting can influence the balance of incison. This is gained from cumulative clinical experience in which surgeon and therapist confer frequently.

Surgical Procedures

The splint maker must understand the details of any surgical proc- edure if it is to be helped by external splinting. It is the mer- rual responsibility of therapist and surgeon to share information; therapists must diligently study anatomy and surgical procedures. Therapists who observe surgical procedures are more readily able to visualize the influence and movement of the normal structures when approaching the hand from the surface.

BASIC SCIENCE

Pathology of Stiffness

The general response of hand connective tissue to immobilization in the presence of edema is increased resistance to differential glide of the many tissue layers. The “one wound-stre strear” theory ex- plains that stiffness and limited glide can be distant from or local to the injury site.62

The mechanical properties of connective tissue are determined by the collagen fiber arrangement and the cross-links between adja- cent collagen molecules.63 Peacock uses the analogy of a nylon thread (as collagen fiber), which is relatively inelastic. But a nylon stocking—in which the fibers are arranged so that cross- linking allows elasticity—is very elastic.64 Sear production demonstra- tes a disorganized arrangement of collagen fibers, such that the “nylon stocking” loses its elasticity.

Human Tissue Response to Stress

Connective tissue responds to stress deprivation by progressively shortening and to constant tension by displaying plastic elonga- tion,65 described by some as a “growth response” of the tissues.66 The need is for prolonged methods of splint application, as this growth-adaptation is not a quick response.

Until drugs are produced which can influence wound healing, stress is the only effective method to influence collagen fiber orien- tation.63 Sear, displaying a disorganized collagen fiber structure and decreased elasticity, will show increased organization of its fibers and increased elasticity as a response to the splint stress.63 Splints can also control the extent of normal wound contraction. If the circumference of the splint provides too equal or greater force than that of wound contraction, deformity is prevented.

CHOOSING SPLINTS BASED ON BIOLOGIC STAGES OF HEALING

The type and amount of stress needed to effect fiber realignment in the tissues is, to some extent, influenced by the stage of healing based on biochemical activity in the wound.67 These stages in the healing may be prolonged or overlap. The clinical experience of the therapist ultimately focuses judgment on what splint type is most appropriate and when it should be applied. It would be ideal if the splint application were a science, but the practicality of trial and error is still a frequent determinant of the tissue tolerance to stress.

Stage I: Inflammation

The initial reaction to injury is a vascular and cellular response which removes devitalized tissue; this stage lasts about 5 days. Static splinting during this stage provides the desired rest. Only in mild injuries is intermittent active motion appropriate; the period of active motion must be short and be limited by the inflammatory pain and edema. Splinting should also include some means of gen- tle compression.68

Stage II: Fibroplasia

After the initial inflammation subsides, injured tissues undergo rapid change. Immature collagen with disorganized fibrils replaces normal tissue. It is this disorganized collagen that bonds the tissue layers, creating one scar, and interferes with gliding planes be- tween each tissue.67

At the beginning of the fibroplastic stage, the low tensile strength of the wound allows only gentle active motion and positional splint- ing. Static splints may support the joint in full extension, allowing the patient to concentrate on flexion during the day. Patiens with a mild flexion contracture, who have little resistance to passive joint motion, can regain full motion with a simple roller splint that holds the joint in its maximum degree of extension.68 In the latter part of the fibroplastic stage, gentle dynamic splinting can encourage the collagen fibril and collagen.

Stage III: Scar Maturation

After about 6 weeks the fibroplastic stage is complete; similarly applied stress can present long-term stiffness. Excessive stress can delay or prevent the progression of healing.

Since the new tissue is in the early stages of maturation, brief periods of dynamic stretching are often effective to mobilize stiffened joints.68 Interimat stress application pro- vides adequate force to produce plastic deformation because tissue resistance during the early part of this stage is small. A joint that responds to gentle sustained manual traction and shows a gentle slope to torque angle measurements responds to a short period of stretching (Fig. 111-11).62-74 Some recommend a short period if semirigid referring to reduce contracture, and then dynamic spin- ning applied intermittently or maintain position.63 The idea is to apply the dynamic splint at the beginning of this stage when tissue resistance is responsive to intermittent stress.

The therapist and surgeon must learn to “read” the response of the hand to the stress of the splint. If signs of inflammation con- tinue, serial static splinting may allow rest for the tissues, while re- gaining motion with serial positioning. When the patient lives some distance from the clinic or can use the splint only when not working, a static progressive splint may be best. The patient can remove a static progressive splint for daily tasks and the splint can be ad- justed to accommodate improved motion.

During the final phase of scar maturation the amount of col-lagen decreases and the wound becomes stronger.75 The cells have new interlinking bonds that provide resistance to motion. These
First Class Levers
All splints are first class levers (Fig. 111-12) with axes of motion at the joints to which they are applied. The fulcrum (split base, or outrigger with attached force application) affects joint motion. To null joints into flexion or extension, splints must have three points of pressure distribution: one is at the level of the joint; the other two are as far away from the fulcrum as possible to maximize leverage.35,76

The length of the forearm piece is relevant for pressure distribution when the weight of the hand must be carried by the splint.77 Finger loops should be placed as far from the joint axis as possible so that the torque is maximized.16,76

Mechanical Effectiveness
Understanding splint types and tissue responses to them is the basis for effective splinting. Splint efficacy is limited by design accuracy, fit, and brace consistency.

Even Distribution of Pressure
The splint must fit accurately. This is accomplished by careful molding and well distributed pressure. Burrell advocated the use of non-padded plaster of paris to relieve areas of high pressure over the dorsal surface of each finger. In contrast, concentrated pressure over a small dorsal area of each finger, it is distributed over as much surface area as possible. The leading edge of the block ends at the joint so that all force is specifically directed to the joint axis.
Commercial dynamic splints frequently fail to offer the individual shape and pressure distribution needed, making wearing uncomfortable. Fitting of a commercial splint designed to apply joint pressure should be done by a knowledgeable person. If the commercial splint cannot be adjusted to distribute pressure evenly, it should be abandoned and a custom one constructed.

**Prolonged Tension**

Because tissue attenuation occurs most effectively with a low load and long application, 2.16,28–30 it is always preferable to have a small force that the patient can tolerate for increasing time, rather than a larger force that can only be tolerated for short periods. The tension needed to place tissues at the end of their elastic limits is all that is needed. 52 It is important to make patients aware of this splinting principle since the patient's goal should be increased wear time before force is increased. Similarly, if the patient cannot comfortably wear the splint beyond a few minutes and the splint fits well, the force should be decreased.

The consistency of force application in dynamic or static progressive splinting is most often related to the patient's tolerance to the level of force applied. There continues to be a debate about the optimal amount of force necessary to achieve maximum gains. 2.16,30,31,33–35,65,70 Ischemia of local tissues produced by application of the finger splint may be a more realistic limiting factor. 52,53,66,67,90 paper bands, 52,53 and springs 90 have been studied to find out the amount and consistency of force applied by each, but the conclusive work has yet to be published. The pressure becomes increasingly relevant as application time increases. The intermittent application of force, which is the nature of most splinting, increases the amount of force that can be safely tolerated. 52,53 However, and caution should indicate total and range time (TERT) for the force. 90

The more nurture the scar, the more likely experienced therapists are to choose a greater amount of force. 70 Until the question of "How much tension?" is answered, the patient's comfort remains the best way of deciding maximum effective force over time. 90

**Easy Adjustment**

Any splint used to gain motion should be easy to remodel, inexpensive to replace, and quick to adjust; the splint must be adaptable to the anticipated joint change.

The low temperature plastics allow quick remolding and adjustments to be made to adapt to new positions, to decreased edema, or to relieve unwanted pressure areas. Planter allows quick construction of a new splint with small materials cost. The use of metal outriggers permits adjustments to simply bending the wire (Fig. 111-13). As finger joint flexion increases, the line of pull of the finger loop needs to be refocused closer to the palm. Alternatively, an extension improves, the outrigger needs to be shortened and place more proximally. 52,53

**Perpendicular Force**

The construction of a dynamic or static progressive splint requires attention to additional biomechanical principles.

A force used to stretch a joint should pull at a 90-degree angle to the long axis of the bone. 52 The outrigger end is secured close to the point of application of force. The outrigger reduces the line of pull and keeps it as close and in parallel as possible to the splint base. This leverforce system is of value only if a secure splint base has been applied that is intimately conformed, has neutral cast, well distributed, and accurately stabilizes the proximal joints. Perforce efficiency of dynamic and static progressive systems often alter, either the outrigger or its attachment to the base is unstable. If the outrigger is significantly unstable, it will deform before the tissues change.
SPLINTS FOR CLINICAL PROBLEMS

Splints for Joint Stability

Splints that support unstable joints are used to protect a healing tissue from external stress. Splinting can be as simple as a tightly sutured ligament to the adjacent digit or a sophisticated splint to reduce an unstable dorsally dislocated joint, permitting progressive motion (Fig. 111-14).

Splints can also provide an external substitute for loss of ligamentous restraint, such as for patients with rheumatoid and other connective tissue disorders. With multiple joint deformities, the splint may provide long-term functional assistance, or temporary assistance until surgical stabilization can be undertaken (Fig. 111-4).

Splints to Reduce Joint Tightness

Only a skilled manual examination can decide the character and amplitude of joint tightness. If passive joint motion does not change when the proximal and distal joint positions are changed, isolated joint tightness can be proved. If other soft tissue contractions are present simultaneously, the extent of the joint limitations is obscured. Certain motion may need to be regained before the potential for other structures can be learned (e.g., passive PIP joint flexion)

must be gained to allow effective evaluation of intrinsic tightness (See Chaps. 68 and 69.).

Many designs and types of splints are used to treat joint tightness. Common joint limitations and splinting approaches follow.

Proximal Interphalangeal Joint

The stage of healing and the amount of resistance from a PIP joint contracture determines the design of the extension splint. Some surgeons and therapists advocate serial casting as the first choice (Fig. 111-6); others recommend dynamic (Fig. 111-5) or static progressive splinting (Fig. 111-7). The joint effusion common after PIP injuries may also prevent full extension. For that reason, when the PIP joint is swollen, regardless of the stage of healing, a period of serial casting is recommended to gain motion while reducing edema. Chain the gains can be maintained with intermittent use of a static or dynamic splint.

Regardless of the splint chosen, care must be given to avoid pressure over the dorsum of the proximal interphalangeal joint. Because full interphalangeal extension is rarely needed for daily function, proximal interphalangeal extension splinting must be applied for a long time to reestablish balanced motion at this joint.
The intimate tendon and PIP joint anatomy means that the extensor frequently loses its ability to glide unimpeded across the joint capsule. Most often the frustration with splints used to reduce joint tightness of the proximal interphalangeal joint is the inability of the splint to gain full passive interphalangeal joint extension, but it is the recurring active extensor lag. The intrinsic muscles responsible for interphalangeal extension have little power or mechanical advantage. Even after proximal interphalangeal joint passive extension is gained, there must often be intermittent, day, and full-time tight, splitting in extension. This must be balanced with intrinsic muscle exercises (IP joint extension with metacarpophalangeal joint flexion).

**Metacarpophalangeal joint**

Metacarpophalangeal (MP) joints which lack passive flexion resist the best splinting efforts because of the anatomy of the collateral ligaments and metacarpal heads. The collateral ligaments want change in length more than 20 degrees at 60 degrees of flexion is achieved. Many versions of dynamic splints cause flexion, because of the problem of the splint slipping distally instead of increasing the MP joint flexion. Prevention of distal slippage is accomplished by intimate molding, use of a dorsal splint base plus a palmar bar, and, most importantly, an oblique stop at the thumb base. Construction details prevent slippage and improve splint tolerances (Fig. 111-15).

**FIG. 111-15.** A dynamic-splint made of being with regions proximal interphalangeal joint extension. ASHT splint classification SF-PIP extensor mobilization, type (1).

**FIG. 111-16.** A dynamic-splint to a deep metacarpophalangeal joint flexion is carefully contoured and assured moist for full metacarpophalangeal flexion to occur. ASHT splint classification: SF-MP flexion mobilization splint type (14). (Note: Wrist can move through partial range while hand is in splint.)
More revive metacarpalphalangeal joints will respond to the prolonged positioning within a snug static plaster of path splint, which is removed only for short periods for splint changes until the required motion is regained. Either a dorsal and palmar plaster slab can be applied, or a wrist cast can have a dorsal plaster expansion added over the proximal phalanges to gain MP joint flexion.

Bunnet's splint of choice, and a splint well recommended by many, is the "kneuckle bender," which is built like the MP joints only. The lack of scaphoid conformity and the splint's hard material makes discomfort a major issue, as its application can cause pressure areas and prolonged edema.

**Wrist Joint**

Serial static splinting (casting), dynamic extension splinting, and static progressive splinting may all be used to regain wrist extension necessary for function. The primary design element required for an effective dynamic wrist splint is a hinge, connecting the metacarpal and forearm components (Fig. 111-17). The wrist must be carried through its normal arc of flexion instead of being compromised by the splint force.

Unlike splinting of the IP and MP joints to regain motion, the wrist can be splinted to increase motion, and the patient still retains use of the hand. Serial static splints, adjusted at the patient gait's wrist extension, can be worn during daily activities. A less resistant wrist joint may respond to intermittent use of a dynamic splint. As for other stiff joints, active wrist motion through the available passive range must be repeated often to maintain the gains made with the splint.

**Splints to Reduce Muscle-Tendon Tightness and Adherence**

Tightness of a muscle and adherence of a tendon along its path both cause limited motion. These may occur from direct trauma or when a muscle-tendon unit is immobilized to protect a more severe injury. An atrophied muscle shortens its resting length by 10 to 40 percent owing to the change in compliance of the elastic elements. Adherence of the tendon along its path is most often associated with direct trauma to the tendon at tendon birth-death and is more likely where tendons are constrained by pulleys.

Tendon adherence and muscle tightness are both demonstrated by a distinct difference between the ease of digital joint motion when the proximal joints are positioned first in flexion and then in extension. Jow motion to the point of adherence is necessary to pull on the size of adherence. These points of adherence demonstrate the positions needed for effective splinting. For example, to stretch the extensor muscles, the wrist must be held in flexion while the fingers are continually flexed. To elongate the adherence of a repaired extensor tendon over the metacarpals, only joints adjacent to the repair (metacarpal) need to be included in the splint (Fig. 111-16). The type of splint chosen depends on the amount and chronicity of the tissue resistance to stretch.

**Intrinsic Muscle Tightness**

Intrinsic muscles are particularly prone to lose their elasticity in the presence of edema and impaired hand motion, such as from crush injuries. The smaller intrinsic muscles with less extension fixations require prolonged positioning in a stretched position to regain their elasticity. When manual stretching is not effective in reducing anesthetic tightness, use of intermittent splinting should be undertaken (Fig. 111-18). The importance of a position of MP joint hyperextension and digital splint slipping prevents many patients from being effective.

**Extrinsic Muscle Tightness**

Because of their greater bulk and extension, extrinsic flexor muscles often regain their normal elasticity in response to manual stretching alone—especially if tightness results from immobilization instead of direct injury. Either serial static splinting of all joints concentrically or dynamic splinting of the digital joints while the proximal joints place the muscle as stretch are effective.

**Splints for Nerve Injuries**

Splints for nerve injuries apply force, but those used for the hand affected by nerve injury correct motion to create a fascicle of the normal muscle balance. Biomimetic states "... insufficient force for the last motion with just enough force so that when the opposing normal muscles are relaxed, the part falls into the proper position."

**FIG. 111-17.** Adjustable splint to regain wrist extension into, a commercially available wrist hinge component. ASHT splint classification—wrist extension mobilization, type C [1].
and yet allow the normal muscles, when activated, to carry out the full range of motion.\textsuperscript{64}

**Median Nerve Palsy**

The primary functional deficit with median nerve palsy is the inability of the thumb to abduct and oppose; the thumb adductor is unopposed. As muscle return is awaited, the abductor pollicis brevis and the opponens need to be placed in their shortest position and the web space must also be passively maintained. A small spica to stabilize the thumb in a position where pinch can occur is the design of choice (Fig. 111-19). Night splinting is used to maintain the full span of the web space.\textsuperscript{65} The traditional C-shaped design of commercial splints neither adequately stabilizes the thumb for pinch nor maintains the maximum width of the first web.

**Ulnar Nerve Palsy**

In isolated ulnar nerve palsy, the use of a static dorsal MP joint blocking spica stabilizes the extrinsic extensor pull out to the dorsal mechanism of the proximal interphalangeal joint (Fig. 111-20), which activates full PIP extension and thwarts MP hyperextension.\textsuperscript{66} This blocking spica prevents PIP joint contractures and overstretching the denervated intrinsics muscles. Additionally the

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**FIG. 111-18.** A dynamic spica to stretch tight intrinsic muscles prevents the metacarpophalangeal joints in full extension while the rubber hand force is driving the interphalangeal joints. AHT spica classification. RF-5 MP PIP flexion mobilization, MP extension, type 1.\textsuperscript{13} (Wine is included in the spina.)

**FIG. 111-19.** A small spica stabilizes the thumb in median nerve palsy. AHT spica classification: thumb CMU restriction, type 0.\textsuperscript{11}

**FIG. 111-20.** The spica prevents metacarpophalangeal joint clamping is isolated ulnar palsy but allows full finger flexion. AHT spica classification: RF-5 MP extension restriction, type 0.\textsuperscript{21}
blocking action of the splint prevents the development of subconscious patterns, thus allowing earlier isolation and strengthening of remaining intrinsic muscle function.

Some authors have recommended spring coils to help MP flexion. Correctly gauging the force necessary to assist with MP flexion and at the same time to resist metacarpophalangeal hyperextension is difficult. A static splint which blocks MP hyperextension is recommended by the author for its ease of fit and tolerance.85,86

Radial Nerve Palsy

The hand affected by radial nerve palsy has potential for normal function because of intact palmar sensibility, extrinsic flexors, and the intrinsic muscles. A splint should support the wrist and reestablish the normal tenodesis. Many authors have advocated dynamic splinting12,13,79,86,108,109 or static wrist splinting12,110 to simulate a more normal tenodesis. This author recommends a splint design with a static line that allows full finger flexion and functional wrist exten-

sion as the finger flexors tighten (Fig. 111-21). Suspension of proximal phalanges prevents the wrist from dropping into flexion and achieves MP joint extension. (Intrinsic IP extension is preserved.) The metacarpophalangeal joints develop extension contractures in this splint only if injury to the peripheral nerves has diminished the normal finger flexor power.

Splints for Tendon Injuries

Flexor Tendons

The results of flexor tendon surgery have been enhanced by postoperative protocols or constrained motion that follow the application of external splints (Fig. 111-22). This method has proved superior to postoperative immobilization.84,85,103 To accomplish greater tendon excursion within a safe range, modifications include a palmar pulley for full distal interpha-

langeal flexion,12,109 devices that provide consistent resistance to finger extension,12,109,111 have been designed to decrease the frequency of IPP joint contractures.109,112,113 Cooney et al. have advocated a tenodesis splint that allows greater excursion.109

The exact splint type, joint positions, and intricacies of the postoperative protocol vary among surgeons and therapists. (See Chap. 47 and 48.) Individuality will continue until it is known exactly “how” to get the best results. The postoperative care of flexor ten-
dons requires close and frequent communication between therapist and surgeon. To prevent tension on the healing tendon, MP joints are often kept in maximum flexion. Although MP flexion may assist in preventing IPP flexion contractures by facilitating full interpha-
langeal extension, the motion available in the splint is via the intrinsic muscles which makes extrinsic flexor activity more difficult when active motion begins. For that reason, the author uses only 15 to 20 degrees of MP flexion in these splints.

Extensor Tendons

The rationale of early tendon gliding within a safe range is also applied to the postoperative management of extensor tendons (Fig. 111-23).114,115 (See Chap. 49.) Some clinicians continue to use static splint immobilization for clean, uncomplicated, extensor tendon lacerations. These “simple” splints should hold the tendons at max-
imum proximal excursion since adherence with immobilization will occur. Many physicians are hesitant to hold MP joints fully ex-
tended because of the risk of losing normal MP flexion. In iso-
lated clean tendon lacerations which are splinted for the minimum time necessary to protect the repair, it is the author’s experience

FIG. 111-21. This radial nerve palsy splint design recreates the normal tenodesis pattern of the hand. ASIF: splint classification; wrist extension, MP flexion mobilization; MP flexion, wrist extension mobilization; type W3. (From: Colditz JC. Splinting for radial nerve palsy. J Hand Ther 11:17-18, 1978, with permission.)

FIG. 111-22. A postoperative splint to limit excursion of digit with a repair flexor tendon. ASIF: splint classification: RF flexion mobilization, extension restriction type 4[7].
that loss of MP joint flexion is rare. Joint immobilization in midposition has a frequent problem of extensor lag. The weak extensors (with the best patient effort) have difficulty overcoming adhesion. Conversely, such a tenodesis laceration held at maximum extension has only to gain glide distally i.e., gain flexion, which is always easier because of the greater power of the flexors.

Although excellent results have been demonstrated with early active motion via dynamic splinting, many clinicians still reserve dynamic splinting for complicated wounds or extensive tendon lacerations near the dorsal reinaugal.

**Splints for Scar Skin Tightness**

Skin tightness is demonstrated by applying an elongation force to adjacent skin or scar. Branching, tension within a scar line, or immobility of skin graft or sutured bed is observed. Often when skin limits (joint) motion, placing the skin in a slack position allows increased motion at adjacent points. Because splinting effectively elongates the scar through adaptation of the surrounding normal tissues, the joints proximal and distal to the scar should be included in any splint. The splint is applied directly to the scar and an interfacing (silicone, etc.) mold between the splint and the scar assures total conformity. Pressure frightens the scar while the splint maintains scar length.

The problem of splitting to reduce skin tightness is the need for prolonged splint wear, which often interferes with hand use. To solve this dilemma one may apply a night splint to position the tight scar in the maximally stretched position. During the day elastic gloves or pressure molds (held in place with elastic wrap) provide consistent pressure and maintain as much length as possible while still allowing hand use.

**Splints for Fractures and Joint Dislocations**

Most splints made by therapists for fractures and dislocations are to help deal with joint tightness which results from these injuries. These splints have been described. Therapists working closely with hand surgeons often frequently provide immediate splitting of stable hand fractures to facilitate early motion. This approach has been developed based on Sarmiento’s fracture bracing and Burkhart’s functional

**Splints for Congenital Deformities**

Only congenital anomalies due to failure of differentiation are affected by early external splinting. Congenitally in both the newborn and the teenager may well respond to splinting. The author’s technique is serial static splinting in the newborn and dynamic splinting (Fig. 111-13) in the teenager who exhibits exacerbation of a PIP flexion contracture. Mina et al. have shown that with dynamic splinting only 5 of 62 congenital patients failed to improve and recommend that this splint be reserved for those in whom conservators treatment fails.

Other selected congenital problems can be helped by splinting. A light thumb-in-palm deformity (abumed spasticity) can often be helped by a period of splinting. Radial cut hands require external splinting to maintain hand use in neutral until surgical stabilization. Soft tissue releases, such as with simple synovitis, also benefit from postoperative splinting to maintain the new web space.

**Splints for Dupuytren’s Contracture Release**

Following excision of Dupuytren’s tissue, the greatest challenge for the therapist and surgeon is the prevention of stiffness of the small joints. Most postoperative protocols use splints to maintain finger extension. This author prefers a volar splint that provides direct pressure to the scar. The splint is part of the early postoperative care, initially removed only intermittently to allow active flexion. As the scar matures, an interface mold is made to

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**FIG. 111-23.** A postoperative split to little extension and alert on the internal extensor tendons in dorsal of hand. Extension is limited by the palmar block. ASIFT splint classification: R-B MP extension mobilization, flexion restriction type (C).

**FIG. 111-24.** A functional fracture brace for stable proximal phalanx fractures allows interphalangeal joint motion. ASIFT splint classification: SM MP restriction, type (I).
provide direct pressure and the splint is worn only at night for an additional 2 months. The use of a soft dorsal leather strap helps provide comfortable long term dorsal counterpressure over the joints (Fig. 111-25).

Splints for Rheumatoid Arthritis
Nonoperative
Resting splints for the rheumatoid hand support joints, reduce inflammation of the synovium, encourage muscle relaxation, and eliminate pain with motion.124,125 Splints that support unstable joints often allow increased function when worn either all the time or for specific activities.

Because of the multiple joint involvement frequently seen in rheumatoid splinting is often required for one joint because another's surgical treatment. The therapist and surgeon must not be misled into splinting the most obvious deformity. It may be a more subtle deformity that is the greatest functional obstacle (e.g., instability of the thumb IP joint) (Fig. 111-26).

Postoperative
The role of postoperative splinting in directing new collagen fibers following MP joint arthroplasty is well documented.126,127 Elastic traction to maintain alignment of the digits while allowing early motion is an integral requirement for success of the surgery. Several commercial splints and components are used to help the splint-maker easily adjust finger position (Fig. 111-27). Many other surgical procedures for rheumatoid patients can be enhanced by splinting. These include dynamic splinting for repaired flexor or extensor tendons, positional or dynamic splinting to stretch postoperative tightness, or splints to protect a joint arthrodesis.

SPLINT PRESCRIPTION
Current Issues
Splint prescription today often reflects a ‘code’ between a therapist and a surgeon that can be deciphered only by the parties involved. The terminology used most often reflects the terminology colloquial to the surgeon’s training institution. Many surgeons are unaware of the vast number of custom and commercial designs available for various problems and may request the same splint for many different conditions.

Surgeons who work with well-trained hand therapists may rely on the therapist to decide on the form of the splint—but only if the details of diagnosis, treatment, and splint purpose are accurately relayed.128,129

FIG. 111-25. A postoperative splint to gain full metacarpophalangeal and interphalangeal joint extension following release of Dupuytren’s contracture. ASHFT splint classification: MP-SM MP-PIP DIP extension mobilization, type 49.

FIG. 111-26. A unstable thumb interphalangeal joint of a patient with rheumatoid arthritis is (B) stabilized by a small splint. ASHFT splint classification: thumb IP RD restriction, type 41. (RD = radial deviation.)
The ASIT Splint Classification System recommends that splint function is the primary information that must be communicated. The (spray) form or manner in which the function is achieved is secondary. Only when therapists and surgeons alike receive similar training in naming and prescribing splints will standardization become a reality in clinics.

FIG. 111-28. Splint prescription form recommended by the American Society of Hand Therapists. Note recommended use of abbreviations. (From Splint Classification System, American Society of Hand Therapists, 401 N. Michigan Avenue, Chicago, 1982, with permission.)
ASHT Splint Prescription Recommendations

To ease communication between individual therapists and surgeons, as well as among hand therapy professions in general, standardization of splint prescriptions is necessary. The ASHT recommends a splint prescription form to identify the desired splint function (Fig. 111-28), which communicates precise referral information (Fig. 111-29). Whether this form is used or the information is written out by the surgeon, a detailed diagnosis must accompany the splint prescription form.

COMPLICATIONS

Complications from the application of hand splints are absent from the literature, generally because these are infrequent, and the complications likely short-lived. Any splint applying a force restricting motion can prove detrimental if applied incorrectly, used improperly, or worn too long or with excessive force.

Insufficiency

Often the patient is limited in splint wearing time by discomfort created from splint application. This may be due to an isolated pressure point (e.g., over the ulnar styloid or simply a rough edge producing local irritation). All splints applying force to the hand should be worn in the clinic for ≥15 min. The hand should then be checked for pressure before the patient leaves. It may be the smallest detail that limits effectiveness of the splint.

Other signs of insufficiency in splinting are prolonged redness, swelling, and joint pain. The therapist and surgeon must then reduce or eliminate splinting time and pressure until the hand shows signs of greater equilibrium. Patients must understand the need for a balance between rest and motion. The immobility of the splint application must be offset by the right amount of active motion.

Ineffectiveness

Elaborate splints may be constructed and applied to the patient’s hand, but sometimes the response to splinting is disappointing. Most often this results from poor splint mechanics, or the patient may assume the splint is the primary means of regaining motion. There must be an active home therapy program to reinforce the gains made by the splint. Splinting is only a part of a complex, biopsychosocial treatment approach which must always be used with an adapted exercise program.19

UNSOLVED ISSUES

Hand splinting has become part of the routine care of many surgical and nonsurgical patients, but it has yet been proved that splinting is a necessary part of postoperative programs. A continuing responsibility remains to demonstrate efficacy. In this era where time and resources are scrutinized, therapists and surgeons will be required to demonstrate the best use of splints. These data will determine what type of splint, worn for what period of time, with what amount of force, provides the best results for each condition. Therapists and surgeons will be asked to show how custom splints are justified instead of less expensive commercial ones. Surgeons, therapists, patients, and now also patients' care managers need to be continuously educated.

The author appreciates the editorial and artistic assistance of Neal A. Watson.

ANNOTATED REFERENCES


Not only a great historical source, this also an excellent review of principles of hand splinting which has endured.


In this comprehensive text on hand rehabilitation, not only are there excellent chapters devoted to hand splinting, but various splinting techniques are also included in many other chapters.

This text, which focuses primarily on effective mechanical principles of splitting, is the most comprehensive text available on hand splitting.

Brand PW, Holliner A: Clinical Mechanics of the Hand, 3d ed. St. Louis, Mosby Year Book, 1993. Although not a text about splitting, it is mandatory reading for anyone seeking to understand how stress influences human tissue.


REFERENCES


