Low Profile Dynamic Splinting of the Injured Hand

(hand rehabilitation, splint design rationale, splint fabrication)

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Dynamic splinting is a well-accepted modality in gaining joint motion in the injured hand. Presented is a splinting design system referred to as "low profile" dynamic splinting whereby high outriggers are avoided. A review of the literature reveals that this technique is based on the original design approach used by Dr. Sterling Bunnell. Described are the basic principles of the low profile design system, with illustrations of the system in specific splints and specific construction details. This splinting system is indicated for a stiff hand that has sustained direct trauma. Hands with a muscle imbalance secondary to a central nervous system or peripheral nerve lesion require a different splinting approach, which is not within the scope of this paper.

The use of dynamic splinting to facilitate rehabilitation of the injured hand is well documented as being part of the therapy process (1-9). The distinction between the use of static, or resting, splints during the initial phase of healing and dynamic splints during the rehabilitation phase has prompted a great interest in the design and construction of these dynamic systems. Bunnell's statement is still a well-accepted rationale: "Active splinting is physiological splinting." (2, p 733) The goal of dynamic splinting is to provide low amplitude of force over a prolonged period to influence the synthesis of new tissue. Rather than to provide a quick stretch to the soft tissues that allows them to immediately return to the original length, the goal is to keep the tissues in a constant state of mild tension so that cells multiply and proliferate in response to the need created by the stress applied by the splint (3, 4).

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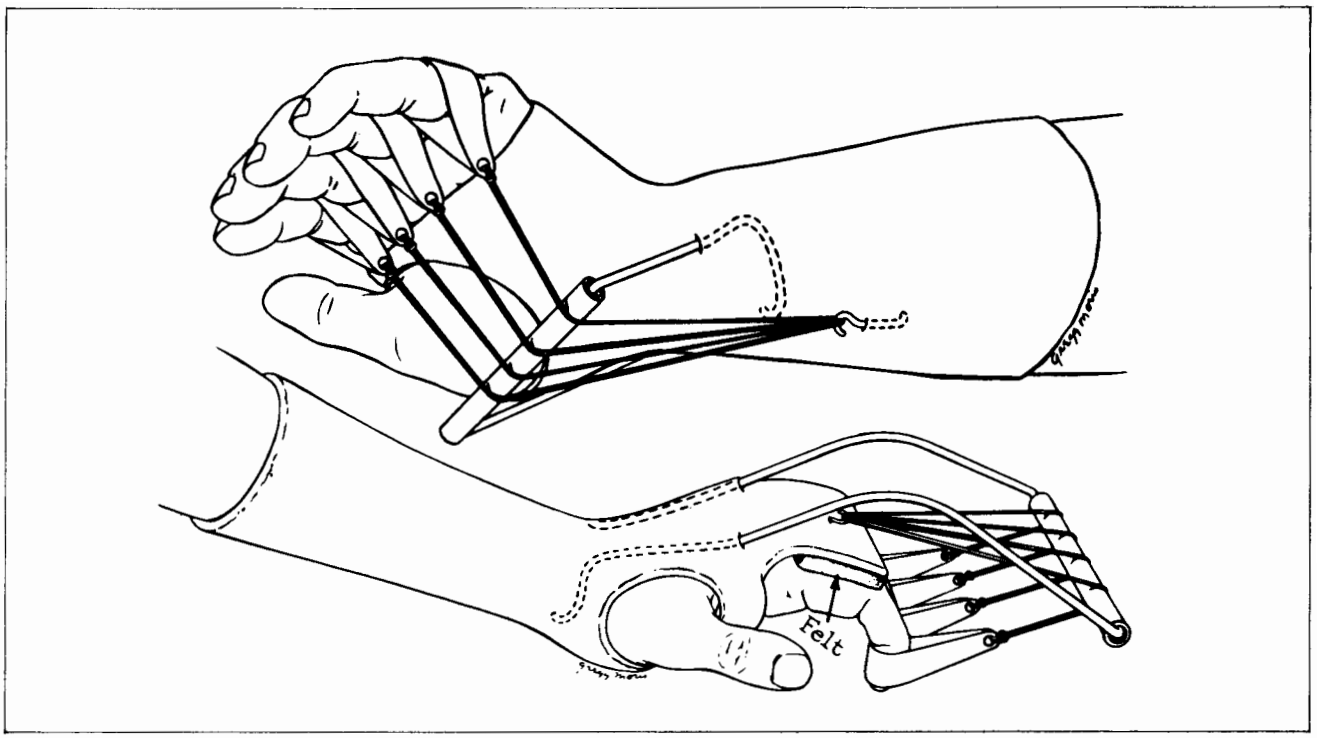


Figure 1
Splints designed by Dr. Sterling Bunnell. Used by permission from *Bunnell's Surgery of the Hand* (4th Edition). Joseph H. Boyes, Editor, J. B. Lippincott Co., 1964.

Splints must be well designed and specifically applied if the forces have the power to alter tissue synthesis.

History. Historically, orthotic systems for the upper extremity were made by the blacksmith or untrained prosthetist who fashioned a device based on the individual need of the patient (10). Dr. Sterling Bunnell, who coordinated the establishment of hand surgery services in army hospitals during World War II, prompted the evolution of hand surgery as a surgical specialty. In addition to describing and documenting wound care and operative techniques, he designed plaster splints with wire outriggers for specific problems and defined the rationale for splinting the injured hand (1, 2, 11). As the specialty of hand surgery grew, the need for splints grew; thus many of Bunnell's original designs became commercially available and are still widely used today. Many of these early designs were of the low profile type: force lines were redirected to be kept parallel to the splint base to prevent large bulky splints and awkward projection arms (Figure 1). This design was in keeping with Bunnell's criteria for splinting: "[Splints] should be cheap and light but still not offensive to the eye, easy to make, and of simple construction, instead of elaborate and with too much machinery. Splints should be easily adjustable and not too bulky. Bulky splints are in the way and so are prominent outriggers. It is more convenient for the patient if the splint can pass through a coat sleeve." (11, p 103) Unfortunately, the desire to make splints available to everyone meant that the custom-molded plaster splint base was sacrificed for the use of steel and aluminum that permitted easy manufacturing. At times the low profile was sacrificed for ease in attaching a high metal outrigger. Although the literature presents numerous isolated splint designs over the years, Bunnell's original designs are still popular. Peacock has described the wire and plaster technique as it was used in the military hand centers during World War II (9), but little else is found in the literature specifically addressing the low profile approach. The advent of low-temperature plastic splinting materials, which allow quick design and application, has made fitting custom splints a vital part of hand rehabilitation.

Design Theory. The rationale for applying force to stretch a joint is to provide a line of pull at a 90° angle to the axis of the long bone that is the distal articulation of the joint in question (5, 8-10). The low profile design adheres strictly to the basic principle of a right-angle line of pull. The outrigger end is located as close as possible to the point of application of force. This allows it to be of minimal length and contributes to the streamlined profile. The outrigger redirects the line of pull and keeps the line close to and as parallel as possible with the base of the splint. The fingerloop is attached to string carried over or under the outrigger (acting as a pulley), and then the rubber band is at-

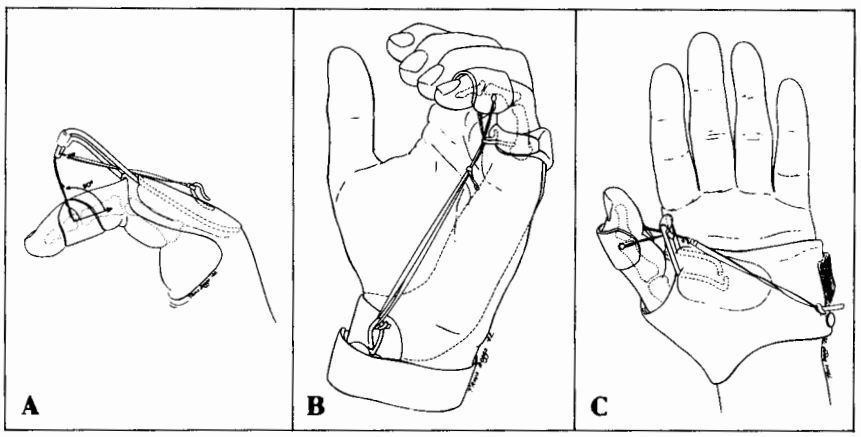


Figure 2
Low profile technique for (*A*); proximal interphalangeal joint extension (*B*); proximal interphalangeal joint flexion in the last ranges; and (*C*) thumb metacarpophalangeal flexion.

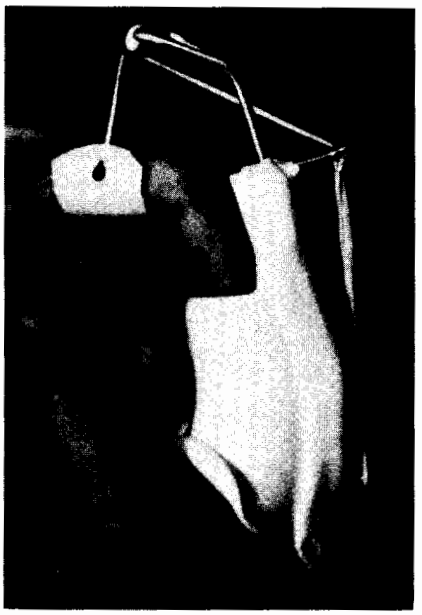


Figure 3
Severe flexion contracture of the proximal interphalangeal joint splinted by redirecting the line of pull multiple times, thus avoiding a long outrigger arm.

tached to the string. The rubber band is secured to the splint base at some distant point by hooking it over a small metal hook attached to the splint base (Figure 2*ABC*). This technique is particularly helpful for intricate splinting problems involving one finger joint. This low profile method provides patients with mechanically sound and yet more cosmetically acceptable devices.

Materials

Splint Base. The goal of low profile splinting is to provide an intimate mold on the hand that gives specific support so that the pulley systems can be small, specifically located, and often quite intricate. Custom-made splints are feasible because the low-temperature plastic splinting materials are readily available. The polycaprolactone group (Polyform, K-Splint, Aquaplast) is recommended for low profile hand splinting because of its ability to mold intricately and bond easily. Malick has described the specific capabilities of these materials (8). Although plaster of paris can be intimately molded, it is not recommended for use because of longer construction time and lack of water resistance.

Outrigger. Metal has long been used for outriggers; frequently, coat-hanger wire, because it is so readily available, has been the item of choice. An outrigger is only as stable as the material from which it is made. Thus any material that can be bent easily with the hands can be deformed easily by the force it is carrying. Although any intrinsically stable material may be used, brass welding rod is recommended (7, 9). Brass rod is available from welding suppliers by the pound. The following sizes are recommended: 1/8 inch (3.175 mm) diameter for large outriggers (dynamic PIP extension of all fingers with MP joints blocked or dynamic MP flexion of all fingers); 3/32 inch (2.381 mm) diameter for shorter outriggers, especially outriggers for a single finger splint; and 1/16 inch (1.587 mm) for all hooks and loops and pulleys that are short and close to point of application.

Choice of fingerloop materials is not crucial as long as the size of the loop and line of pull on the loop allow good distribution of pressure. Attaching string to each side of the loop rather than joining the loop with one common hole helps to distribute pressure (Figure 3). Loops can be of leather, vinyl, or plastic, but loop material that is soft and stretches excessively when force is applied is not suitable for this technique.

Nylon string is used to attach to the fingerloop and then slide across or under the pulley before application of the rubber band. This string must be strong and not stretchable (some nylon fishing line is stretchy) and must not fray easily. Waxed string is not suitable since it does not slide easily across the pulley. Recommended is 6 oz. FF white NYMO Monocord available from orthotic suppliers.

Rubber bands used are the standard gauge sold by any office sup-

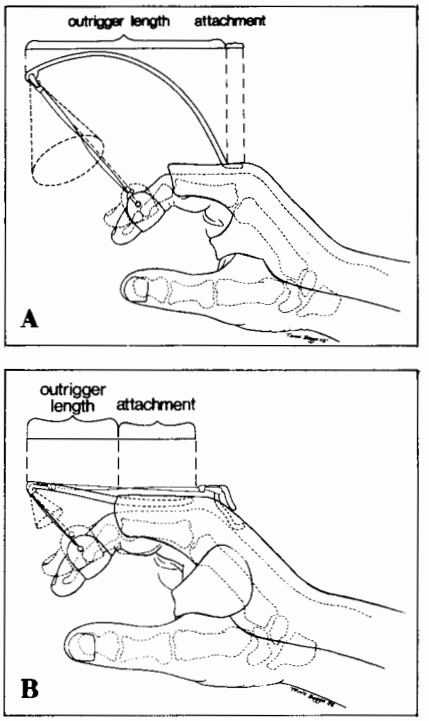


Figure 4
High profile (*A*) illustrates proportionately longer outrigger length in relationship to area of attachment and larger radius of possible attachment than in low profile (*B*).

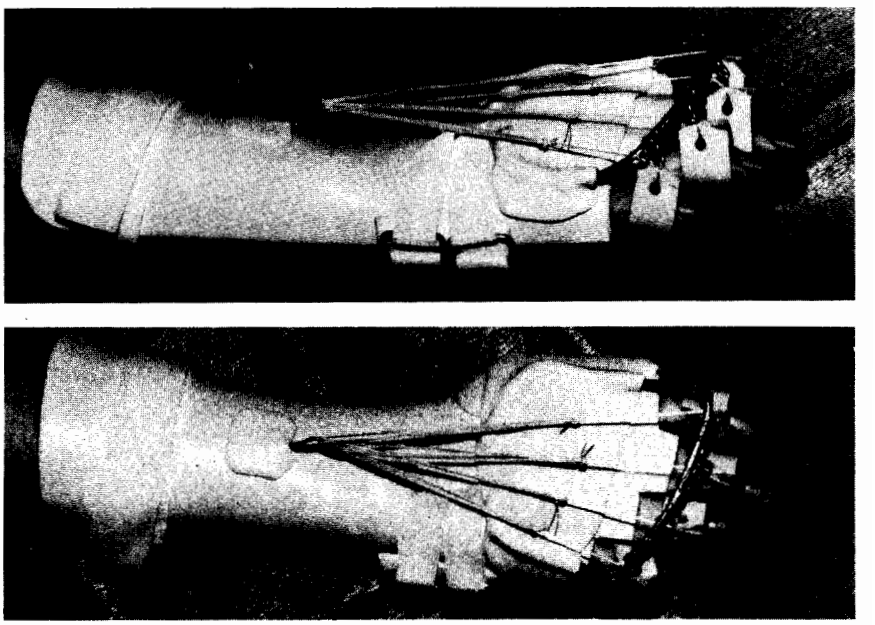


Figure 5
Low profile outrigger for proximal interphalangeal extension with wrist stabilized.

plier. Size is chosen according to which joint is being stretched, the post-traumatic status of the hand, and the length available over which to stretch the rubber band.

Technique

Providing a Force Perpendicular to the Long Bone Axis. The goal of the splint is to provide a force perpendicular to the axis of the long bone that is the lever arm for moving the joint (Figure 2*ABC*). This is difficult when one is splinting for flexion of a finger joint, since there is little room for conventional outriggers on the palmar surface while the joint is stretching into flexion. With the low profile system, the fingerloop is attached to string and the string is pulled through a small loop in the palmar part of the splint base; then the rubber band is attached to the string and secured at a distant point on the splint base. This redirection of force facilitates gains in the last ranges of flexion of a finger joint (Figure 2*B*). This is a great advantage, for example, when attempting dynamic flexion of the index or long finger metacarpophalangeal joint, since leaving the thenar area mobile is advisable. A small loop attached to the narrow palmar bar redirects the pull obliquely across the palmar area. This redirection is frequently of value in allowing a splint to be efficient and yet immobilize as few uninjured joints as possible. Straps or elastic bands are used by many therapists to gain the last few degrees of flexion, but the constriction of blood flow makes these less tolerable for long periods than a dynamic splint system, with specific force arms.

Conversely, while providing an extension force to stretch a severe flexion contracture of the PIP joint, the high profile outrigger often seems excessively bulky in order to be in the correct position to provide the 90° line of pull. With the low profile system, the line of pull can be redirected more than once if necessary so that it is kept closer to the splint base (Figure 3).

This system is of value *only if* a secure splint base has been applied that is intimately conformed, has pressure areas well distributed, and accurately stabilizes the proximal joints. The force applied by the outrigger system will only be valuable if it is effecting movements in the prescribed joint and not in a poorly stabilized proximal joint that has normal mobility.

Providing Outrigger and Base Stability. The efficiency and amount of force applied with dynamic traction will alter if either the outrigger or its attachment to the splint base is unstable. The outrigger will then deform before the tissues do, if it is significantly unstable (5). Stability of outriggers is directly correlated to their length, since the same force applied to a longer lever arm will generate an increased force at the fulcrum (Figure 4*AB*). These factors also can be altered by the material used, but given the same material, the longer the outrigger the less stable it is. When the outrigger is used as a pulley, it is of minimal length and has increased stability.

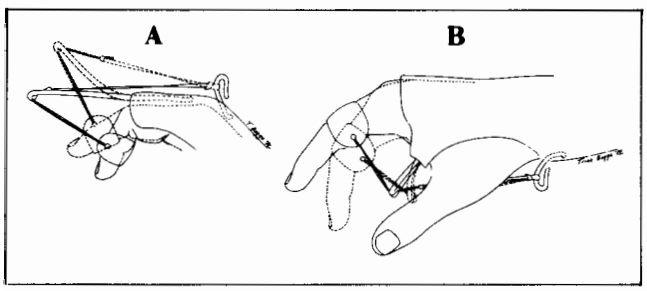


Figure 6
A simple bend of the wire outrigger maintains the correct line of pull as extension range (*A*) and flexion range (*B*) is gained.

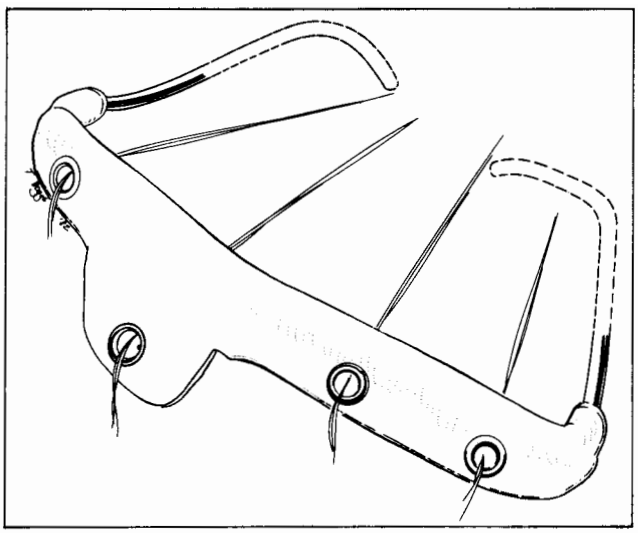


Figure 7
Splinting material used over wire outrigger base allows easy location of pulleys to accommodate varying joint angle deformities. Metal eyelets prevent a groove being worn in the material.

Although brass welding rod is recommended, the thermoplastic splinting material may be used for outriggers. One must pay particular attention to achieving stability when using the plastic materials. Clinical experience proves that it requires more construction time and the plastic material is harder to adjust than the wire system.

Use of the wire outriggers as pulleys suggests some specific clinical techniques for outrigger stability. When attaching any outrigger, whether for all fingers or one finger, it is helpful to bend the base of the outrigger to conform to the shape of the splint base as intimately as possible; fewer air spaces and a more total contact makes a more stable attachment. An additional bend parallel to the base increases stability. The parallel bend serves two purposes: it increases the surface area over which the outrigger is applied, and it prevents distal or proximal shifting or twisting (Figure 2*ABC*, Figure 5). Since metal conducts heat, the outrigger wire can be heated quickly by a heat gun and applied to the splint base. This allows total contact since the hot outrigger seats itself into the plastic splinting material. This technique also prevents the outrigger from moving while laminating a piece of splinting material over the outrigger base. After initial positioning of the outrigger, clean around it thoroughly with solvent. To achieve good lamination, heat a piece of splinting material so it is very pliable and clean one surface of it with solvent. Then laminate it over the outrigger base. Never heat the splint base. Cover as large an area as is reasonable with the laminated piece to increase the purchase on the outrigger for total contact (Figure 5). Laminating as far toward the distal edge of the splint as possible over the outrigger contributes to maximum outrigger attachment stability. Attention to these details in construction increases the stability of the splint base itself. If the attachment of an outrigger is over a small surface area, as is sometimes done with high profile designs, then the force generated at the point of attachment is significantly higher than if distributed over a large area of the splint base. This may deform the base rather than stabilize it (Figure 4*AB*).

Providing Specific Application of Force. Since forces must be applied at the distal end of the long bone in order to use maximum efficiency of the lever arm (5, 10), the fingerloop attachment must be *precisely* located and maintained at a 90° line of pull. The close and precise positioning of the outrigger pulley with the low profile design increases the ease of fingerloop placement since the radius of application is diminished (Figure 4*AB*). However, a 10° change of position of a joint that is 2 cm away from an outrigger versus one that is 15 cm away from an outrigger will cause the precise 90° line of pull to change more rapidly: that is, the low profile will have earlier loss of correct angle of pull than the high profile (Figure 4*AB*). If this line of pull changes enough to cause the fingerloop to



Figure 8
Technique of soldering 1/16-inch (1.587 mm) brass welding rod to 1/8-inch (3.175 mm) brass welding rod for more permanent outrigger.

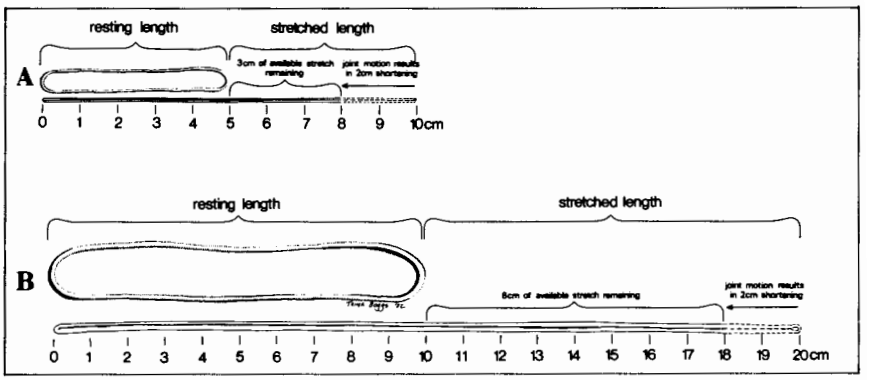


Figure 9
Difference between 5-cm rubber band (*A*) and 10-cm rubber band (*B*) stretched twice its resting length. With joint motion resulting in a 2-cm shortening of rubber band, a greater proportion of available stretch remains in the longer rubber band.

slip, much of the force is lost. One needs to monitor the low profile system closely, and patients should be followed frequently for therapy and splint adjustments.

The purpose and goals of the splint should clearly be explained to the patient by the therapist (8). It is rare to encounter patients who cannot understand the principle of the right-angle line of pull so that they can adjust the line of pull at home with a pair of pliers, or at the least, know when to contact the therapist for an adjustment.

The technique of positioning the metal outrigger on the splint base with dry heat prior to final lamination helps to determine the correct location and line of pull of the outrigger. Frequently, the angles of the tight joints vary greatly, making it necessary to create a different line of pull for each finger. The outrigger pulley system is quickly customized to difficult deformities by simply bending a loop or pulley for each finger.

Distributing Pressure Evenly. In addition to the advantages of providing stable outriggers and bases, the low profile design distributes pressure evenly, as demonstrated by the metacarpophalangeal blocks (or lumbrical bars) molded as a continuation of the splint base. The problems of increased pressure due to decreased surface area contact that the more traditional lumbrical bar provides are thus avoided. Since the leading edge of the block generates force, the block is ended over the joint so as to direct all force to the joint axis (Figure 2*A*, Figure 5). If constructed with correct mechanical forces, high and low profile splints have equal potential for good pressure distribution.

Ease of Adjustment. Ease and speed of adjustment of outriggers to provide a correct line of pull are major factors to consider when using a therapist's time efficiently. Use of welding rod permits adjustments by simply bending the wire. For example, as finger joint flexion increases, the line of pull of the fingerloop needs to be directed closer toward the palm. Bending the wire toward the palm corrects the line of pull (Figure 6*A*). Alternately, as finger extension improves, the outrigger needs to be shortened and placed more proximally (Figure 6*B*). This also can be achieved by simply bending the wire. If the improvement has been so great as to merit construction of a new outrigger, then dry heating the metal outrigger as previously described allows it to be easily removed from the base and another placed in the same location. Since metal conducts both cold and heat efficiently, dipping the outrigger in cold water hardens the laminate more quickly than waiting for multiple layers of splinting material to cool.

At times, using the splinting material as a pulley may be useful; for example, when constructing an outrigger for all fingers. One may use the welding rod for the outrigger frame to ensure stability and ease of adjustment, and then add a piece of splinting material over the wire and punch holes to act as pulleys (Fig-

ure 7). Locating the holes after the outrigger is attached to the splint base on the hand offers easy correct location of the pulleys. Since friction of the string sliding on the splinting material will wear a groove, a metal eyelet can be set into the hole with the dry heating method (Figure 7). This technique is particularly helpful in a hand with the finger joints at varying angles since the splinting material may be lowered to provide varying locations of the pulley holes. If the splint is to be worn for a long time one may solder the 1/16-inch rod that is formed into multiple loops onto the 1/8-inch rod, or the base outrigger. Use of a small gauge copper wire to wrap these together facilitates soldering (Figure 8). Use of a 2.5 amp solder gun with 60/40 rosin core solder is recommended.

Providing More Constant Tension. The accepted means of supplying force is by a stretched rubber band (9, 13) (except the spring steel coil designs). The goal of low profile splinting is to provide as long a length as possible over which to stretch the rubber band, since a longer rubber band stretched twice its resting length provides a more constant tension than a shorter band stretched twice its resting length (Figure 9). If the joint moves a few degrees, more tension is left in the rubber band stretched over the longer distance. Many high profile designs provide a relatively short distance for rubber band stretch, thus requiring use of a short, tight band that quickly exhausts its available stretch. Placing the outrigger pulley as close as possible to the point of force application facilitates use of the maximum length of rubber band as does applying the rubber band to the string immediately after it passes over or under the pulley (Figure 2*ABC*). If the patient is to actively exercise in the splint, enough string must be left beyond the pulley before attaching the rubber band to allow excursion of the string without the knot catching on the pulley. A mark on the string as it passes through the pulley demonstrates tangible progress to the patient as the mark moves farther away from the pulley. If working for active excursion, the mark provides a tangible goal for the harnessed motion.

Providing a Less Cumbersome Device. The splint should be cosmetically acceptable and also permit the patient to continue with daily tasks with relative ease. The ability to perform tasks while in the splint often determines a patient's compliance to the prescribed splinting program. Since the goal is a period of prolonged stretch, a splint that can be worn for long periods must be provided. Custom-made splints, based on a specific analysis of the needs of the hand, and where the goals and rationale are thoroughly explained to the patient are rarely left unworn. Also, wearability is enhanced if the splint can be applied and removed quickly and easily. A splint that is one integral unit when removed helps the patient to comply. Use of the outrigger pulley system is facilitated by making the pulley a full circle so that when the fingerloop system retracts it will stay in place. When pulling up and over an outrigger, the addition of a piece of splinting material to close the loop will prevent loss of the fingerloop (Figure 2*A* and *C*).

Summary

The basic principles of low profile dynamic splinting have been described. A historical perspective of the evolution of low profile splinting and the basic principles and construction techniques have been presented. A materials overview has been presented, together with a clarification of technique and rationale: providing perpendicular forces, providing outrigger stability, providing specific application of force, distributing pressure evenly, providing easy adjustment, providing more constant tension, and providing a less cumbersome device. Practicing therapists can use these splinting techniques in direct clinical application.

Acknowledgment

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