Relative Motion Splint: Active Motion After Extensor Tendon Injury and Repair

Wyndell H. Merritt, MD

The relative motion splint was initially developed to facilitate postoperative rehabilitation after repair of extensor tendon injuries at the dorsum of the hand and forearm. It has subsequently been used for rehabilitation of sagittal band injuries and after repair of closed attrition extensor tendon ruptures in rheumatoid arthritis. This is much less awkward than other braces and can readily be worn during normal past-time and work activities. This so-called immediate controlled active motion splinting protocol has also more recently been applied to both operative and nonsurgical rehabilitation for boutonniere deformity. (J Hand Surg Am. 2014;39(6):1187–1194. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)

Key words Tendon therapy, extensor tendon, laceration, boutonniere, sagittal band.



E XTENSOR TENDON INJURIES HAVE traditionally been treated by either 4 to 6 weeks' immobilization, with possible loss of flexion owing to joint stiffness, or dynamic splinting that may (or may not) provide passive gliding of the injured tendon but requires wearing an awkward device.¹ More recently, early active "short arc motion" is proposed for extensor tendon injuries of the finger, but this requires careful monitoring and intensive therapy with active motion only under therapist supervision during the first 3 weeks, and immobilization in a "palmar resting splint" followed by a home program that requires a compliant patient to do home active motion exercises.²

Relative motion splinting, also known as immediate controlled active motion splinting,³ encourages immediate full active function of the hand, unrestricted other than 15° to 20° less extension or flexion

From the Department of Plastic Surgery, University of Virginia, Charlottesville, VA.

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Corresponding author: Wyndell H. Merritt, MD, Department of Plastic Surgery, University of Virginia, 7660 E. Parham Road, MOB I, Suite 200, Henrico, VA 23294; e-mail: wyndell@hotmail.com.

0363-5023/14/3906-0030\$36.00/0 http://dx.doi.org/10.1016/j.jhsa.2014.03.015 of the metacarpophalangeal (MCP) joint, depending on the injury. We have used this patient-friendly management technique in long extensor lacerations for over 30 years,⁴ and then more recently for boutonniere deformity, sagittal band rupture,⁵ and side-to-side tendon repair after rheumatoid extensor tendon ruptures in caput ulnae syndrome, preserving full interphalangeal joint motion and minimizing the need for intensive hand therapy.

RATIONALE

The relative motion concept is simple. When an injured tendon is placed in 15° to 20° less relative motion than adjacent tendons from a shared muscle (extensor or flexor), it will experience markedly less force than adjacent tendons,⁶ regardless of the position from full extension to full flexion (minus the 15° to 20° difference at the MCP joint). With long extensor repair in zones IV to VII, all extensors function like the single unit extensor digitorum communis muscle. Independent extensors recover equally well as the common extensors when placed in 15° to 20° greater MCP extension than the adjacent digits (Fig. 1). This concept is also effective in reducing tension across sagittal band ruptures and side-to-side tendon transfers in caput ulnae syndrome. We call this the *relative* motion extensor splint."

In boutonniere deformity, the lumbricals have 4 times the excursion of the more powerful interossei,

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.



FIGURE 1: Because of the 1-motor system, a relative motion extension splint relaxes the repair regardless of the MCP and IP joint positions.

and therefore are the principal extensors of the interphalangeal (IP) joints.⁸ The lumbricals arise from the flexor digitorum profundus tendons that come from a single motor unit. Therefore, placing the injured extensor hood digit into 15° to 20° greater MCP flexion relative to adjacent digits places laxity in that profundus tendon, which relaxes that lumbrical from its downward pull while increasing tension on the extensor hood, encouraging dorsal repositioning, regardless of whether the patient fully flexes or extends (minus the 15° to 20° MCP extension compared with its neighboring digits). We call this a relative motion flexor splint.9 It is easily demonstrated in the cadaver by creating a large boutonniere deformity and placing a cotton tip applicator or tongue blade over the proximal phalanx of the operated digit and beneath the adjacent digits, then pulling on the common extensor muscles (see Videos 1 and 2, available on the Journal's Web site at http://www.jhandsurg.org). It can also be demonstrated in a patient with an acute closed boutonniere deformity and supple joints (Fig. 2).

TECHNIQUE

Long extensor repair—zones IV to VII

After long extensor tendon repair, a thermoplastic yoke finger splint is constructed, placing the repaired

tendon(s) in approximately 15° to 20° greater MCP extension than adjacent digits for 6 weeks, preserving full IP range of motion. The wrist is placed in approximately 20° to 25° extension with a separate splint for the first 3 weeks to avoid passive tension on the suture line from full composite wrist and finger flexion (possibly unnecessary; see "Pearls"). After 3 weeks, the wrist splint is discontinued and only the finger splint is used for an additional 3 weeks (Fig. 3).

Thereafter, full flexion is usually present or is quickly recovered (98.5% of the opposite hand flexion was present at 6 wk, and 96.2% of total active motion⁵). Full normal work and play activities are encouraged in the splint (Fig. 4). The compliant patient must understand that the finger splint is worn constantly for the initial 6-week interval. Therapy goals are to make sure the patient recovers full IP and MCP flexion and extension in the splint and in adjacent digits as soon as possible after repair. Thereafter, only occasional monitoring is needed. In our series, an average of 8 therapy visits were needed, and return to work averaged 18 days. Additional therapy after 6 weeks was unusual in all but those with complex injuries or delayed repair and splinting. The average discharge was at 7 weeks after surgery.³ Hirth et al⁹ demonstrated notably earlier recovery of motion and return to work.



FIGURE 2: A Acute boutonniere deformity. **B** The deformity is easily corrected by simply pushing the proximal phalanx into greater MCP flexion. **C** Boutonniere splint for the little finger, with no wrist component for 6 weeks.



FIGURE 3: Immediate active motion after long finger extensor repair: A wrist splinted 3 weeks; B finger splinted 6 weeks.

Sagittal band rupture—acute and chronic

Patients with acute sagittal band rupture, less than 2 or 3 weeks after injury, can usually centralize the tendon when placed in extension and will experience

pain relief soon after relative motion extensor splinting, even when flexing in the splint. These patients are splinted in a similar fashion to long extensor repairs, without the wrist splint component. Success is evident



FIGURE 4: Unrestricted work and recreational activities are encouraged in the splint.

by encouraging full finger flexion in the splint (minus 15° to 20° at the MCP joint), which should be pain free without tendon subluxations. This splint is then maintained for 6 weeks (although others recommend 8 wk).¹⁰ Little or no additional therapy is usually needed once full motion in the splint has been achieved.

Surgical techniques to correct chronic sagittal band rupture usually recommend 8 to 10 weeks of immobilization with a variety of surgical procedures, from direct repair to various tendon slips from juncturae tendinum, or a strip from the extensor digitorum communis. We prefer to create a tendon graft pulley directly into the head of the metacarpal,⁵ done using palmaris longus, juncturae tendinum, a strip of extensor retinaculum, or a strip of extensor indicis proprius (Fig. 5). All of these have been used successfully, followed by relative motion extensor splinting for 6 weeks using only the finger component and no wrist splint. Full activity and use is encouraged and full recovery of flexion should be expected. It is useful to perform the surgery with local anesthesia to appreciate the value of the splint (see Videos 3 and 4, available on the Journal's Web site at http://www. jhandsurg.org). Although the current author has not done so, other surgical methods to centralize the tendon should be expected to heal equally well with this relative motion extensor splint that permits active use and protects the repair. This technique has been successful in rheumatoid arthritis patients, although 1 developed recurrence after 7 years.

Boutonniere deformity—zone III

Correction of acute closed boutonniere deformity when full passive extension is possible can be demonstrated by simply placing a cotton tip applicator over the proximal phalanx of the injured digit and beneath the proximal phalanges of the adjacent digits; sometimes, simple digital pressure on the proximal phalanx will suffice. If full proximal interphalangeal (PIP) extension is possible, simple relative flexion splinting alone (no wrist component) for 6 weeks should result in preservation of full extension and flexion, with functional use during the splinting interval (Fig. 6). This concept is demonstrated in cadaver dissection and clinical cases (see Videos 3 and 4, available on the *Journal's* Web site at www.jhandsurg.org).

Open acute boutonniere repair is best accomplished using local anesthesia with epinephrine (either lidocaine or bupivacaine), especially in complex wounds to ensure the delicate balance is restored between the intrinsic tendons and the extensor hood. Once accomplished, motion can be preserved by relative motion flexor splinting, although early therapy monitoring is usually needed to ensure that the patient fully extends and flexes. The patient can resume usual hand use, and is encouraged to do so within the restraints of the splint for 6 weeks (Video 4).

Chronic boutonniere has been a surgical conundrum, with poor results reported, especially in older patients and those with fixed flexion contractures.¹¹ All authors agree that initial nonsurgical efforts to obtain passive PIP extension by serial casting and dynamic splinting are warranted, but this is too often followed by loss of active extension and recurrent flexion contractures. It is hard for patients to tolerate the functional impairment of 2 to 3 months of gutter or dynamic extensor splinting that is often recommended.¹² Once serial casting achieves maximum PIP extension, if it is better than 30° , the author accepts this and uses relative motion flexor splinting full-time for 3 months. This splint is compatible with active use of the hand, permitting full flexion, and patients are therefore compliant. At the end of 3 months, the degree of improved PIP extension has been maintained, with follow-up as long as 3 years, in the author's experience. It is always preferable to obtain and maintain full extension, but this researcher has been pleasantly surprised to find that less than full extension can be preserved using the relative motion flexor splint. Should this fail, surgery remains an option. Surgical release of collateral ligaments and volar joint capsule contractures at the same time as extensor hood reconstruction and lateral band reposition (using local anesthesia to be accurate) should be favorably managed with this splint, avoiding the ankylosis often caused by prolonged Kirschner wire fixation. However, the current author's experience with serial casting and prolonged relative motion flexor splinting has





been sufficiently favorable that late surgical correction combined with splinting has not yet been attempted.

Caput ulnae syndrome with tendon ruptures

Attrition rupture of the ulnar long extensor tendons in rheumatoid arthritis (Vaughn-Jackson syndrome) as the result of relative dorsal prominence of the ulnar head creates a circumstance in which immobilization after ulnar head resection and tenosynovectomies will likely cause adherence of tendon repair and loss of gliding. This usually is a chronic condition in which direct tendon repair is not possible, and the author used side-to-side repair of the ulnar ruptured tendons to an intact radial tendon in concert with ulnar head resection, extensor tenosynovectomies, dorsal radial wrist sensory neurectomy, and translocation of the radially based extensor retinaculum beneath the tendons attached to a dorsally repositioned extensor carpi ulnaris tendon, along with bone anchor

attachment of the ulnar shaft to the radius. It is possible to create a pan-type relative motion finger splint to avoid tension on the tendon repairs, making sure their relative motion is in proper concert for a full 6 weeks while IP and MCP motion is permitted and wrist motion is gradually recovered. The therapy demands and monitoring is far more extensive than with the extensor and flexor relative motion splints, with the wrist maintained at rest the first 3 weeks in supination, and the fingers as well as the wrist in a gutter extensor resting splint at night. It has even been possible to recover neutral finger extension and full flexion after rupture repair of all 4 common ulnar extensors and the extensor digitorum communis to the extensor indicis proprius alone, using tendon grafts to the extensor digitorum communis and little finger extensor digitorum communis with this postoperative protocol. The proximal ruptured tendons were also attached to the extensor indicis proprius so



FIGURE 6: Boyes test: boutonniere deformity. A Boutonniere deformity of the little finger. B With the PIP joint extended, the DIP joint resists flexion. C The PIP joint is flexed, allowing unresisted DIP flexion. D The tongue blade splint allows active extension, demonstrating a boutonniere deformity. E Relative motion splint.

it became a tendon conduit. Mobilization was gentle and finger pan relative motion splints were sometimes alternated with dynamic splints. It is less demanding when only the ring and little finger tendons are involved (Fig. 7).

PEARLS AND PITFALLS

Long extensor tendon repair

Timing: In our series of 140 patients, the operated digital range of motion was compared with the contralateral digit on the uninjured side, and there was no significant difference using various suture techniques and various surgeons, but there was a substantial difference in those patients whose repair or splinting was delayed by 5 days or more. At 6 weeks, total active motion in those repaired and splinted before 5 days averaged 97.8%, whereas those after 5 days averaged 89.5%.⁵ The decreased total active motion was largely the result of less normal hyperextension at the MCP joint and a few

patients with PIP joint extensor lag. It appears that surgery and splinting within a few days after injury produces substantially better results in long extensors.

Wrist splinting: The author has used wrist splints for the first 3 weeks after long extensor repair because of concern that excessive passive tension might result at the suture line with full composite flexion of wrist and fingers. However, recent reports demonstrate equal results and no complications splinting the fingers alone.⁹ The report by Burns et al¹³ includes an excellent video demonstrating how to construct the thermoplastic finger splint. Therefore, it appears the wrist component is unnecessary, although the current author has continued to use it.

Finally, this concept is obviously not useful for laceration of the extensor pollicis longus or when all 6 finger extensors are severed. Dynamic splinting or immobilization is the author's preference under these circumstances.



FIGURE 7: A Caput ulnae syndrome with ring and little finger extensor tendon ruptures. **B**, **C** Splinted with ulnar 2 tendons at greater extension than the middle finger to which they are repaired. **D**, **E** Final range of motion 3 months after surgery.

Sagittal band rupture

Diagnosis: Patients with closed sagittal band rupture commonly present with a history of a single episode of painful inability to extend, followed by swelling and pain that is increased with palpation over the site of rupture. There is often a slight extensor lag and decreased flexion owing to pain. When the patient is seen days later, the diagnosis may seem confusing, but it can be confirmed by the relief provided by relative motion extensor splinting, reducing pressure on the injured site. It usually requires 6 weeks for sustained relief, although others recommend 8 weeks.¹⁰

Surgery: In the current author's chronic surgical cases, the preference is to rotate the tendon graft pulley so the suture line is within the metacarpal shaft. It is tempting to put a single suture in the graft and test this under local anesthesia, but to avoid disruption place a ribbon retractor, tongue blade, or cotton tip applicator beneath the volar proximal phalanx to provide relative motion protection when actively extending (Video 3).

Boutonniere deformity

In chronic boutonniere cases with fixed PIP flexion contractures and fixed distal interphalangeal (DIP) hyperextension contractures, it can be impossible to distinguish clinically whether this is the result of chronic extensor hood disruption or whether it is flexion contracture caused by volar plate injury¹⁴ or pulley disruption,¹⁵ the so-called "pseudo-boutonniere deformity." In such a patient, this can be best determined on magnetic resonance imaging. However, in the patient with a supple DIP joint and some PIP motion, this can be determined clinically by the Boyes test,¹⁶ noting resistance to DIP passive flexion when the PIP joint is extended as much as possible, and then easy flexion of the DIP joint when the PIP is flexed, relaxing tension on the displaced lateral bands (Fig. 6). If the DIP joint is as easily flexed with the PIP in extension as flexion, a PIP joint volar plate injury or tendon pulley injury should be suspected, most easily confirmed on magnetic resonance imaging. Cadaver studies suggested the Elson test to be more accurate for acute boutonniere injury and the Boyes test to be inaccurate.¹⁷ However, the cadaver does not develop inflammatory remodeling and lateral band fixation in a volar displaced position as does the patient with chronic boutonniere. In the author's experience, the established boutonniere is most easily identified by the Boyes test.¹⁷ Patients with pseudoboutonniere deformity will also need serial casting, and then prolonged dynamic extension splinting, although some have advocated volar plate¹³ and pulley¹⁴ surgery.

Caput ulnae syndrome

It is imperative to repair and maintain the extensors in the proper sequence, with each ulnar digit in slightly more flexion. Whereas the other extensor conditions discussed generally require less hand therapy than conventional methods, these patients require intense individualized hand therapy management. If the patient regains MCP and IP flexion early, care must be taken to avoid tight grip with wrist flexion because of possible rupture. More frequently, patients must be assisted to gain flexion, gliding the repaired extensors over the surgical field after tenosynovectomies and bone resection. Thereafter, patients may develop extensor lag, so they must be rested in full MCP and IP extension, and sometimes assisted by dynamic extension. The retinaculum is usually repositioned beneath the extensor tendons because most of these patients have poor wrist extension before surgery, and extensor bowstringing is not a likely problem. However, in some cases, a strip of dorsal retinaculum is reconstructed if good extension was present preoperatively. Finger extension to neutral is all that usually can be expected, unless only the little finger tendons were ruptured.

DISCUSSION

The relative motion concept to permit early active motion has many varied applications whenever multiple tendons are available from a common muscle. Relative motion flexor splinting can be used to protect flexor tendon repair if early full flexion is found after 3 weeks and the patient wants to engage in full vigorous activity; and it can assist recovery of full PIP extension in patients who are stiff after chronic trigger finger release or other conditions that may cause tight intrinsics. In its best role, relative motion splinting is used in combination with local anesthesia and epinephrine (for example, with intrinsic tendon transfer to restore IP extension or in complex boutonniere repair), which provides an opportunity to verify the success of repair as well as the protection afforded by the splint. Its greatest advantages are the simplicity of concept and ease of use for patients.

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