Jacobs
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Orthotic Intervention for the
Hand and Upper Extremity

THIRD
EDITION

Wolters
Kluwer

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Splinting Principles and Process

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Viscoelastic Behavior of Connective Tissue

Stiffness of the hand is not an increased rigidity of the tissues themselves[1] but a constraint created by cross-linking of the previously elastic configuration of the collagen fibers.[2]

Collagen is a hard, insoluble, and fibrous protein that is found in the extracellular matrix. The word collagen is derived from Kola meaning Glue and Gen meaning producing. Collagen is the glue that keeps our tissues together.

In the dermis, a fibrous network of cells called fibroblasts are present, which play a critical role in wound healing. They produce both collagen and elastin. Collagen provides most of the tensile strength of the tissue in the hand. It can be considered to be stronger than steel. Elastin, like collagen, is a protein which is a major constituent of the extracellular matrix of connective tissue. It is a linearly elastic material that changes with deformation and has very small relaxation effects. Collagen fibers themselves are inelastic, but movement between the collagen fibers imparts elasticity to the tissue.

When an injury occurs, collagen proliferation is accelerated, resulting in the formation of a disorganized layer of collagen that may adhere to skin and restrict the mobility of ligaments, tendons, or joint capsules.[3]

Normal hand motion occurs when these strong, dense connective tissue structures glide relative to one another.[4] Stiffness is caused by the fixation of the tissue layers so that the usual elastic relational motion is restricted by cross-links binding the collagen fibers together.[2, 4–9]

Because of the viscoelastic behavior of connective tissue, as a force is applied, there is elastic behavior up to a certain point (the yield point), and then as additional constant force (creep) is applied, there is further displacement. Removal of the force results in partial return to the initial displacement (relaxation). This viscoelastic response can be appreciated in the stiff hand's temporary response to stretch. This is the key to understanding how to resolve joint stiffness in the hand and why LLPS is the most effective way of resolving digital stiffness long term. The CMMS technique provides the most appropriate LLPS stress and is the treatment of choice for the stiff hand. The change in tissue length and mobility through the use of the CMMS technique is superior to that which can be achieved through the use of mobilization orthoses. Furthermore, once the therapist knows how to apply the CMMS technique, the correct amount of stress will be applied without cause for concern.

Active Motion Resolves Joint Stiffness

The primary motor cortex contains an organized map of motor movement representations, including the hand.

Plasticity is an increase in the cortical area representing the skin surface engaged in the task; therefore, heavily practiced behavior causes cortical plasticity by increasing the size of the muscle groups' representation in the brain. Without attention, plasticity is severely limited.[10]

In the chronically stiff hand, joint stiffness is a result of increased collagen cross-linking. The brief, intermittent nature of passive motion combined with little or no engagement of the somatosensory motor cortex renders passive joint motion ineffective and should be avoided. Furthermore, any forceful stretches result in tissue damage and should also be avoided.[6, 11] Increasing passive motion does not increase active motion. However, increasing active motion, will increase passive motion. There is also no need to apply resistance to joint motion in order to have an effect on joint stiffness.

Active motion through the use of the CMMS technique

Treat Multiple Problems Simultaneously

When an injury to a part of the hand occurs, the entire hand responds to the injury. Previously uninjured structures, undergo the same response to trauma, including fibroplasia, increased collagen turnover, and remodeling. One of the greatest challenges therefore is to preserve the integrity of the uninjured structures. The stiff hand becomes immobilized by edema and tissue adherence. This results in the development of a maladapted movement pattern. As this is occurring, the motor and sensory cortical representation of normal, synergistic motion diminishes and is replaced by a maladaptive pattern instead. When abnormal patterns of movement are repeated over time, they give way to changes in the motor cortex.[12] Resolution of joint stiffness is therefore both a mechanical and cerebral challenge. The sooner the abnormal pattern is interrupted the better. Treatment of the multiple problems that are arising in the stiff hand should not occur independently, but rather simultaneously. Time is of the essence when treating the stiff hand. A delay in the appropriate treatment will rob the hand of the possibility of a full return to function. The CMMS technique is the only technique that adequately addresses multiple problems simultaneously, while reestablishing a normal pattern of motion. One need not wait for chronic stiffness to develop before applying the CMMS technique. The technique should be applied as soon as it becomes evident that traditional therapeutic techniques are ineffective. The presence of wounds should not delay the application of the technique. Caution is only warranted in the presence of infection.

Fibroproliferative Conditions

Fibroproliferative conditions such as Dupuytren disease do not respond well to aggressive therapy. Evidence suggests that overzealous splinting and exercise can increase flare-up and advance the disease process.[13] CMMS has been used effectively to resolve postoperative complications following Dupuytren fasciectomy.[14] Digital flexion has been restored without the need to apply a mechanical force in the form of splinting and without the risk of losing PIP joint (PIPJ) extension. The application of a cast promotes the release of PIPJ tightness as motion of the PIPJ is facilitated in both directions. Scar tissue adherence and edema is reduced so that joint motion can be restored.

Dupuytren disease

Combined Treatment Techniques

Restoring joint motion in the injured hand demands a respect for tissue response and the healing continuum. It is up to the therapist to choose the type and timing of the intervention to successfully mobilize the stiff hand. The ability to transform a newly stiff hand to a functional and mobile one is dependent on therapist skill. The therapist must be able to critically evaluate the stiff hand and determine which anatomical structures are limiting motion. The type of stress applied and the facilitation of adequate joint motion through selective immobilization of proximal joints in order to facilitate distal motion in a desired pattern and range is paramount to a successful outcome. Skilled therapists blend programs to achieve desirable results. At times the therapist may need to let go of achieving multiple treatment goals and solely focus on one goal, for example, immobilize the MCP joints in order to facilitate digital flexion and extension. On another occasion, one may need to achieve multiple goals simultaneously, for example, reduce edema, facilitate joint motion, and reestablish a normal pattern of motion.

Intrinsic and Extrinsic Joint Tightness

One must always assume that in the presence of joint stiffness, intrinsic tightness is present. Full active range of motion can never be restored if intrinsic or extrinsic tightness is present. The design of the CMMS cast is determined by the pattern of motion and location of tightness. The position for immobilizing proximal joints is not arbitrary. It is determined by the location of intrinsic or extrinsic tightness and knowledge of biomechanical principles. There is no need to fear immobilizing the MCP joints in extension as the interosseous muscles are the prime MCP joint flexor muscle(s). When casting is discontinued, MCP joint flexion can easily be regained without further specific intervention toward mobilizing the MCP joints into flexion. The only exception is if there is the presence of specific dorsal adherence resulting from dorsal trauma. Dorsal tissue adherence will prevent MCPJ flexion and will require slow, prolonged stretch into flexion combined with active motion to resolve the tissue adherence and restore joint motion. Joint positioning combined with movement equals results.

Intrinsic and extrinsic joint tightness

CHAPTER 15

(Continued)

Long-Term Gains Require Slow Weaning

The most common mistake that therapists make is to discontinue casting too soon. It is exciting for the patient to make rapid gains in restoring joint motion, but it can be equally disheartening if the stiffness returns because a weaning period was not introduced. Patients must demonstrate the desired pattern of motion for 2 weeks within a bivalve cast before the cast can be discontinued. A weaning period through the use of a bivalve (removable cast) is essential to avoid joint stiffness returning.

Bivalve cast for cast weaning

References

Watson N. (1994). What is Stiffness? *Journal of Hand Therapy*, 7(3), 147–149.

Frank C., Akeson W. H., Woo S. L., Amiel D., Coutts R. D. (1984). Physiology and therapeutic value of passive joint motion. *Clinical Orthopaedics and Related Research*, 185, 113–125.

Merritt W. H. (1998). Written on behalf of the stiff finger. *Journal of Hand Therapy*, 11(2), 74–79.

Madden J. W. (1976). Wound healing: The biological basis of hand surgery. *Clinics in Plastic Surgery*, 3(1), 3–11.

AkesonAmiel W. H.D., Abel M. F., Garfin S. R., Woo S. L. (1987). Effects of immobilisation on joints. *Clinical Orthopaedics and Related Research*, 219, 28–37.

Brand P. W., Hollister A. (1999). *Clinical Mechanics of the Hand*. St Louis: Mosby.

Grauer D., Kabo J., Dorey F. J., Meals R. A. (1987). The effects of intermittent passive exercise on joint stiffness following periarticular fracture in rabits. *Clinical Orthopaedics and Related Research*, 220, 259–265.

Meals R. (1993). Posttraumatic limb swelling and joint stifness are not casually related experimental observations in rabbits. *Clinical Orthopaedics and Related Research*, 287, 292–303.

Peacock E. E. (1990). *Wound Healing*. Philadelphia, PA: W.B. Saunders.

Blake D. T., Byl N. N., Merzenich M. M. (2002). Representation of the hand in the cerebral cortex. *Behavioural Brain Research*, 135(1–2), 179–184.

Namba R. S., Kabo J. M., Dorey F. J., Meals R. A. (1991). Continuous passive motion versus immobilization. *Clinical Orthopaedics and Related Research*, 267, 218–223.

Classen J., Liepert J., Wise S. (1998). Modulation of associative human motor cortical plasticity by attention. *Journal of Neurophysiology*, 79(2), 1117–1123.

Evans R. B., Dell P. C., Fiolkowski P. (2002). A clinical report of the effect of mechanical stress on functional results after fasciectomy for Dupuytren's contracture. *Journal of Hand Therapy*, 15, 331–341

Midgley R. (2010). Use of casting motion to mobilize stiffness to regain digital flexion following Dupuytren's fasceictomy. *Hand Therapy*, 15(2), 45–51.

Case Study Section

The case studies presented here are meant as a teaching guideline only. Treatment and orthosis protocols vary greatly from surgeon to surgeon and from therapist to therapist. The therapist should check with the referring physicians and colleagues to define the preferred treatment and appropriate orthotic intervention.

Case Study 1: Hand Crush Injury

MM is a 27-year-old right-dominant male baker who sustained a crush injury to his right hand when it went into a baguette-making machine. His index finger (IF) and middle finger (MF) were crushed up to the proximal phalanx and his thumb was crushed up to the CMC joint. His ring and small fingers were generally unaffected. He had small superficial lacerations on the affected fingers and thumb that were healing well.

He was referred 10 days postinjury with a diagnosis of right crush injury with MF and thumb distal phalanx tuft fractures and a chip fracture of the MF middle phalanx. He presented with moderate edema and hematoma under the nails of the IF, MF, and thumb. He was generally hypersensitive and unwilling to move his hand, apparently owing to pain. His hand postured with his affected fingers in MCP extension, PIP flexion, and DIP in neutral. His thumb MP postured in hyperflexion with the IP joint in slight hyperextension. This thumb posture suggested an undiagnosed soft tissue injury at his thumb MP joint that would affect active and passive MP extension. This concern was shared with the treating physician and patient. A subsequent radiograph revealed a mild subluxation of the thumb MP joint, confirming the diagnosis of a grade 2 to 3 sprain and extensor mechanism compromise.

The therapist discussed the treatment priorities with MM and the rationale for them. MM was told that most physicians and patients prioritize regaining finger IP flexion. However, the therapist's clinical experience supported prioritizing extension. The patient did demonstrate FDP function, and so prognosis for gaining flexion was excellent. MM learned that if the extensor mechanism was left attenuated over the flexed IP joint, it would almost certainly be permanently lengthened and would never be able to provide full extension again. This would sentence MM to lifelong PIP flexion contractures. MM agreed to the plan.

MM's initial orthosis focused on providing a safe position, with the finger MCPs in maximum tolerable flexion and the IPs in maximum tolerable extension (Fig. 15–33A). The thumb was placed in maximum tolerable abduction with the MP in maximum tolerable extension and the IP neutral. The patient received a custom, volar, hand-based orthosis made of 1/8″ combination rubber and plastic material. This type of thermoplastic provides a rigid orthosis owing to its plastic content while allowing for easier modification because of the rubber content. In conjunction with his orthosis program, the patient was provided with a comprehensive home program of edema control, gentle ROM to the fingers and thumb IP, and desensitization. The orthosis was progressed at each subsequent treatment session to achieve the goal of 75° finger MCP flexion, 0° IP extension, 50° thumb abduction, and 0° thumb MP extension. He rapidly achieved his finger MCP flexion and thumb abduction goals. He progressed in finger PIP and thumb MP extension.

Once the diagnosis of thumb soft-tissue injury was confirmed, the patient was placed in a circumferential, hand-based thumb orthosis made of 1″ QuickCast 2 tape without a liner to allow MM to bathe and wash his hands (Fig. 15–33B). When fabricating such a cast without a liner, extreme care must be taken to keep all parts of the cast smooth and all edges trimmed or folded back on themselves.

For the PIPs, MM received custom gutter orthoses fabricated of 1/16″ thermoplastic with a 1″ strap directly over the PIPs (Fig.

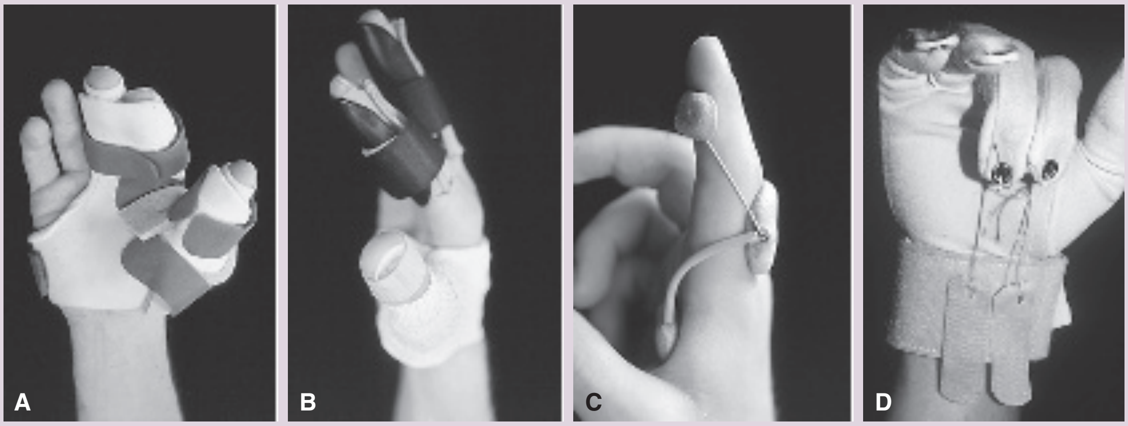

FIGURE 15–33 **A,** Hand-based index finger (IF), middle finger (MF), and thumb immobilization orthosis in the safe position. **B,** Hand-based QuickCast 2 thumb cast and with custom gutter orthoses and 1″ strap directly over the proximal interphalangeal (PIP) joints. **C,** Prefabricated PIP extension mobilization orthosis. The dynamic force is applied through the spring-loaded design of this orthosis. The patient was taught how to adjust the tension. **D,** Static lines provide a static progressive approach to composite flexion of the fingers. Commercially purchased flexion gloves come packaged with rubber bands; however, static line can easily be substituted.

15–33B). The contours of the gutter orthoses were straight volarly at the PIP, and the patient was instructed to tighten the loop strap gradually until the finger met the orthosis. The patient was also provided with a prefabricated PIP extension mobilization orthosis to be used intermittently as tolerated (Fig. 15–33C). MM achieved neutral PIPs 1 week after receiving the new PIP orthosis regimen. It is important to note that during the 7 to 10 days of therapy, MM would not have tolerated the extension forces he was able to tolerate when switched to the gutter/spring orthosis combination.

After achieving neutral extension at the PIPs, the patient received a flexion glove (Fig. 15–33D). The therapist replaced the rubber bands with static line to allow MM to use a static progressive approach to stretch composite flexion of the fingers. MM was instructed to focus on flexion but to return to the gutter orthoses intermittently if he began to lose extension; 2 days later, the patient had increased his flexion by 40° at the PIPs. He could still extend fully.

The thumb cast was changed every other day until the MP reached neutral, for a total of three casts. It should be noted that significant pressure had to be applied to achieve maximum thumb MP extension. Initially, the patient would not have tolerated this degree of force. It should also be noted that after application of each thumb cast, the thumb tip turned a deep red. The patient was asked to remain in the clinic until the color normalized, which it did for every cast.

MM was then placed in a final QuickCast 2 thumb cast that included a rigid dorsal stay made of QuickCast 2; it positioned the thumb MP in anatomical neutral. This orthosis remained in place for 6 weeks, at which time the thumb extensor mechanism was evaluated for competence and a radiograph was taken to confirm anatomical alignment.

Case Study 2: Elbow Capsulotomy and Osteotomy

LS is a 23-year-old college student who sustained a left intra-articular fracture of the humerus, ulna, and radius in a motor vehicle accident. She initially underwent an open reduction and internal fixation (ORIF) but did not have functional ROM after diligent therapy. She then underwent a subsequent manipulation under anesthesia (MUA). This too failed to yield functional motion. She then underwent two osteotomy and soft-tissue releases with the most recent 2 days before presentation. She was referred for fabrication of a custom elbow orthosis to allow her to position herself alternately at maximum extension and maximum flexion.

LS presented with a minimal dressing and a compression sleeve. Her drain was discontinued the same day she arrived for therapy. She demonstrated 135° of flexion and 10° of extension. Her goal was to maintain this mobility, which proved difficult after the previous surgeries.

A static progressive elbow orthosis (MERiT™ SPS elbow extension kit) was chosen to meet the goals for this patient (Fig. 15–34A,B). The orthosis was fabricated using a circumferential approach the humeral cuff and 1/16″ Aquaplast T for the forearm cuff. The orthosis involved an

FIGURE 15–34 A static progressive orthosis allows the patient to position herself at maximum extension **(A)** and maximum flexion **(B)**. Shown is a MERiT™ Static Progressive elbow extension kit.

elbow hinge and an extension outrigger adjusted to provide a 90° angle of pull. The MERiT™ kit, mounted to the forearm cuff, generated tension, which LS could control after receiving thorough instructions about use and precautions. The orthosis line was done in a three-part fashion, with one line attached to the MERiT™ component and a bra hook, one line attached to the extension outrigger and a bra loop, and the last line attached to the humeral cuff and a bra loop. This allowed the MERiT™ kit to attach alternately to the flexion or extension component.

LS immediately grasped the function and use of the orthosis and stated that she was pleased. She was instructed in precautions for skin pressure areas and was taught to monitor the sensation of the ulnar innervated digits while positioned in flexion. Her goal was to wear the orthosis for as many hours as possible during the day, alternating between flexion and extension.

Because LS lived a long distance from the clinic, she was referred to another rehabilitation facility for ongoing therapy. A 3-month follow-up visit revealed she had maintained her excellent ROM.

Additional case studies can be found on the companion web site on thePoint.

CHAPTER REVIEW QUESTIONS

1. Describe three reasons why the upper extremity may become stiff.
2. Give one example of a diagnosis with the most appropriate mobilization orthosis choice and the rationale for use.
3. Briefly describe casting motion to mobilize stiffness (CMMS) and offer an example of when a clinician would consider this treatment.
4. Give an example of three types of different mobilization orthoses (offer an appropriate diagnosis for each type of device).
5. Describe what low-load, prolonged stress (LLPS) is and why this is important clinically.