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# Sagittal band, boutonniere, and pulley injuries in the athlete

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**Abstract**
*Purpose of review* While hand injuries occur frequently in the athletic population, sagittal band ruptures, boutonniere deformities, and pulley ruptures are infrequently encountered. These injuries represent diagnostic challenges and can result in significant impairment. Early recognition with appropriate treatment is necessary to maximize recovery and minimize return to athletic competition. This review will focus on the underlying mechanism, pathophysiology of injury, diagnosis, and treatment of each of these injuries.
*Recent findings* With respect to sagittal band ruptures, boutonniere deformities, and pulley ruptures, the recent literature has been limited in scope. For sagittal band injuries, current efforts have focused on alternative techniques for sagittal band reconstruction. Little progress has been made in recent years with respect to boutonniere injuries in the athletic population; prevention of fixed deformities remains the backbone of treatment. The exact contribution from individual and combined pulley injuries in the creation of bowstringing remains controversial. Recent anatomical studies have failed to definitively answer the question of what degree of rupture is necessary to create symptomatic bowstringing. Favorable outcomes, with respect to both preventing bowstringing and returning to full athletic participation, have been newly reported following pulley reconstruction in rock climbers.
*Summary* Due to the infrequent nature of sagittal band ruptures, boutonniere deformities, and pulley ruptures, current treatment is mostly guided by historically established methods, limited case series, and case reports. Nonsurgical treatment remains the mainstay for most injuries and, if employed early, often precludes the need for surgery. Further anatomical and clinical research, including outcome studies, is necessary in guiding treatment algorithms.

**Keywords** Sagittal band · Pulley injuries · Boutonniere deformity · Central slip disruption · Extensor tendon injuries · Athletic hand injuries

## Introduction

Hand injuries are common in the professional and recreational athletic population. Sagittal band ruptures, boutonniere deformities, and pulley ruptures are infrequently encountered. All three injuries, however, represent diagnostic challenges and can result in significant functional loss. Early recognition with appropriate treatment can often preclude the need for surgery and prevent unnecessary morbidity. This review will focus on the underlying mechanism, pathophysiology of injury, diagnosis, and treatment of each of these injuries.

## Sagittal band injuries

Sagittal band injuries represent zone 5 extensor tendon injuries. The sagittal band attaches dorsally to the extensor hood, runs palmar to insert on the volar plate, and serves as the primary lateral stabilizer to the tendon over the metacarpophalangeal (MCP) joint [1].

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Controversy exists regarding the exact mechanism of sagittal band injury. A direct blow to a flexed MCP joint can result in rupture and has been termed a "boxers knuckle" [2•]. Others have theorized that the injury results from forced digital flexion with the wrist in a position of flexion and ulnar deviation [3]. With this injury, a radial-sided rupture of the sagittal band typically occurs. Rupture results in pain, swelling, and ulnar subluxation of the extensor tendon with MCP flexion. The long finger is most frequently injured due to its greater length and the relative weakness of its fibrous attachments to the extensor hood in comparison to the other digits [4]. Tendon subluxation can result in localized pain and mechanical symptoms of triggering or snapping with digital flexion.

Rayan and Murray proposed a classification system for sagittal band injuries: injury without instability of the extensor tendon (type 1), injury with subluxation of the extensor tendon (type 2), and injury with dislocation of the extensor tendon (type 3) [5]. The diagnosis is made with a thorough history and physical examination of the affected MCP joint. Tendon subluxation or dislocation is demonstrated with active or passive digital motion, reproducing the patient's pain (Fig. 1). Imaging studies are rarely necessary; however, in cases of incomplete injury, magnetic resonance imaging (MRI) or dynamic ultrasound (US) can provide confirmation. Comparison sequences performed with the MCP joint in positions of both maximum flexion and full extension can be useful in evaluating the degree of tendon subluxation or dislocation.

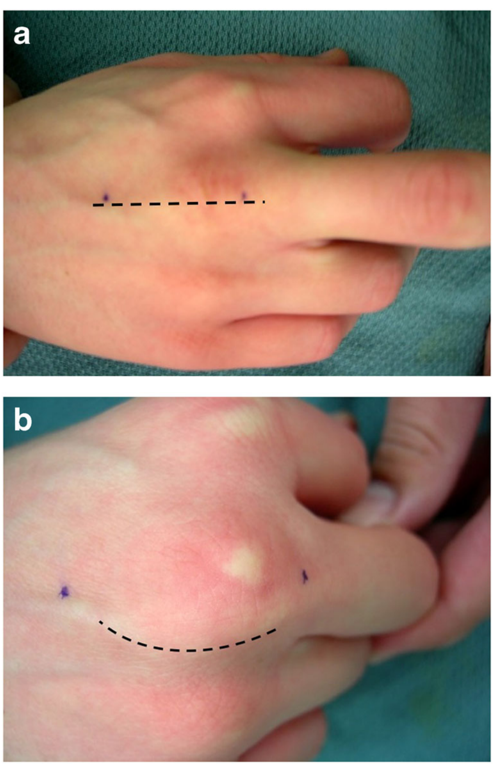


**Fig. 1** **a** Long finger MCP joint in an injured volleyball player; MCP in extension. The *dashed line* indicates the course of the tendon. **b** Tendon dislocation with MCP flexion. The *dashed line* indicates the course of the tendon

Quite often, sagittal band injuries are underappreciated with a delay in presentation common. In the absence of tendon subluxation or in cases with subluxation diagnosed early (within 4–6 weeks of injury), nonoperative management is indicated. While some advocate acute operative intervention with subluxation or dislocation, we reserve this for athletes with type 3 injuries. The injured digit is treated with a custom orthosis which maintains the affected MCP joint in hyperextension or slight flexion for 4–6 weeks [5, 6•, 7]. For patients presenting in a delayed fashion, a trial course of conservative treatment is often still indicated.

When painful tendon subluxation persists in spite of conservative treatment or for injuries presenting in a markedly delayed interval, surgical intervention is indicated. Direct repair of the sagittal band is typically only possible in cases of acute diagnosis (Fig. 2). Multiple reconstruction techniques have been advocated. The goal of reconstructive efforts is to stabilize the extensor tendon against ulnar subluxation or dislocation. Adjacent juncturae, anomalous tendons (such as the extensor medius proprius of the long finger), and distally based slips of the injured tendon have been successfully utilized to provide a pulley which restrains the tendon [8–11] (Fig. 3). Patients are immobilized with the MCP joints in slight flexion using a custom orthosis for 4–6 weeks with early protected motion initiated within 1–2 weeks.

The results of both operative and nonoperative management are limited to case reports and small case series which are not specific to the athletic population. As these injuries are common in the rheumatoid patient, it is important to avoid

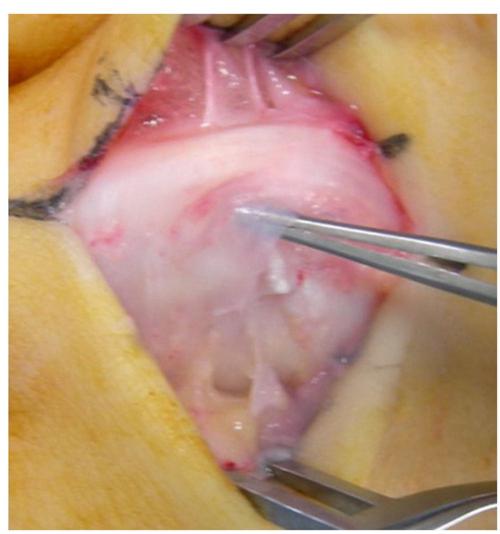

**Fig. 2** Patulous remnants of sagittal band in a case of chronic injury

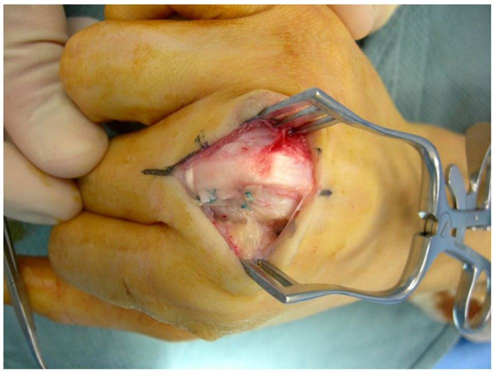

**Fig. 3** Repaired sagittal band injury with distally based "lasso"

comparison with results in this patient population. In general, favorable results have been reported for incomplete injuries treated early. In a series involving a nonrheumatoid patient population of 11 digits with acute injuries treated nonoperatively, Catalano et al. reported 8 digits free from pain and with little or no discernable tendon subluxation. All patients achieved full range of motion [6•]. Surgical intervention for complete injuries has been reported to be successful in returning athletes to return to play [2•, 12].

## Boutonniere injuries

Boutonniere injuries represent zone 3 extensor mechanism disruptions over the proximal interphalangeal (PIP) joint (Fig. 4). During athletic participation, common injury mechanisms include hyperflexion injuries, direct blunt or sharp trauma to the dorsum of the finger, and volar dislocations of the PIP joint. Basketball and volleyball players may be at particular risk for these injuries [13]. Injury to the central slip in isolation will not result in boutonniere deformity. Concomitant injury or attenuation of the triangular ligament and subsequent volar subluxation of the lateral bands will result in the characteristic PIP joint extensor lag and DIP joint hyperextension seen in this condition (Fig. 5). With increased pull from the intrinsic muscles, the lateral bands also migrate proximally resulting in increased terminal extensor mechanism tension and DIP joint extension [14].

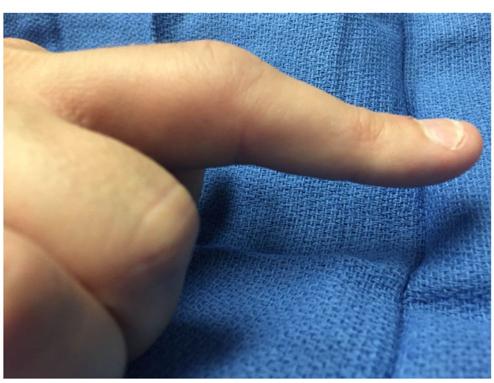

**Fig. 4** Boutonniere deformity

Athletes with central slip injuries may present with seemingly innocuous injury mechanisms such as a "jammed finger" and can be easily missed. Careful history and physical examination are required for a prompt and accurate diagnosis. Pictures of any initial deformity and knowledge of whether an on-field reduction was performed can aid in the diagnosis. As these can be subtle injuries, the clinician should have a low threshold for close follow-up and repeat examination if the diagnosis is in question [15]. For athletes with suspected boutonniere injuries, the Elson test should be performed [16, 17•]. The examiner places the PIP joint in 90° of flexion while the patient attempts to actively extend the DIP joint. With a central slip disruption, patient will demonstrate rigid DIP hyperextension. In the acute setting, some authors recommend administering a digital block prior to performing the Elson test [14, 18]. With a detailed physical examination, advanced imaging is rarely required.

It is important to distinguish a true boutonniere injury from a hyperextension injury to the PIP joint that results in PIP flexion contracture with an intact central slip [19, 20]. This PIP joint flexion contracture secondary to scarring of the volar plate has been described as a "pseudo-boutonniere" injury, and it lacks the pathognomonic rigid DIP joint hyperextension seen in traditional boutonniere injuries. Inappropriate prolonged immobilization of a pseudo-boutonniere deformity would result in increased stiffness and functional loss.

Orthogonal radiographs of the involved digit are utilized to assess for bony avulsion at the dorsal base of P2, volar subluxation or dislocation, and any degenerative changes at the PIP joint. While there is no universally accepted classification system, there are a number of injury characteristics that should be determined. The chronicity of the injury, bony involvement, presence of an open injury, and whether the deformity is passively correctable can all guide treatment decisions. Burton proposed a four-stage classification system, highlighting the importance of determining whether the PIP deformity was fixed or passively correctable [18]. Stage I injuries are passively correctable, stage II are fixed without joint involvement, and stage III have both volar plate and collateral ligament contractures with intra-articular fibrosis. Stage IV includes all the findings in stage III with the additional presence of PIP joint arthritis.

Most acute central slip ruptures can be managed nonsurgically. For athletes with acute, closed central slip ruptures without substantial bony involvement, full-time PIP joint extension splinting for 4–6 weeks is recommended with the goal of preventing boutonniere deformity. It is important to encourage active DIP flexion which will help to keep the lateral bands dorsally located. After this period, the athlete can be transitioned to night splinting for an additional 4 weeks.

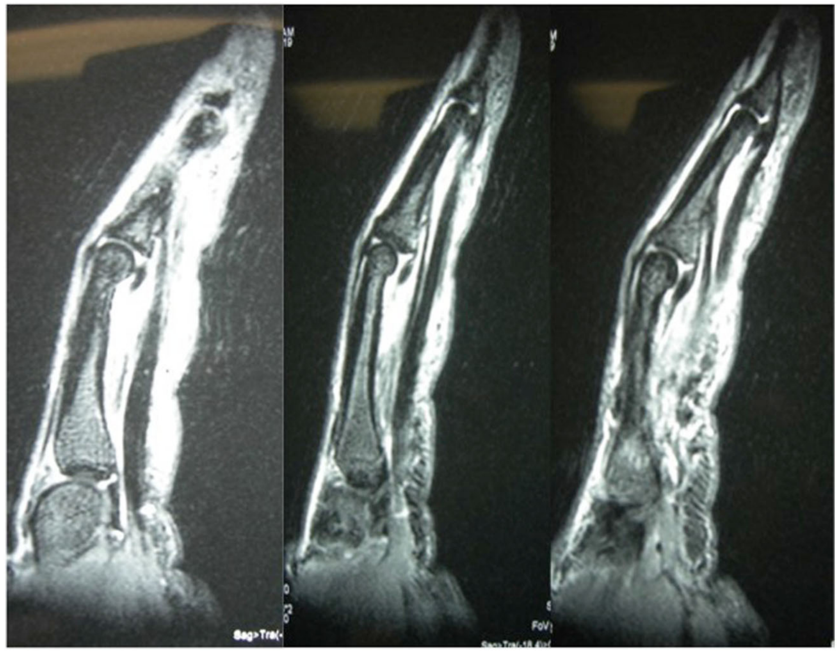

**Fig. 5** MRI demonstrating A2 pulley rupture

Nonsurgical treatment can also be attempted in some chronic injuries where either dynamic splints, progressive static splinting, or serial static casting can be utilized to correct fixed PIP flexion contractures [21].

Operative management includes acute central slip repair, open reduction internal fixation, reconstruction procedures, and arthrodesis. For acute open injuries, irrigation and debridement with central slip repair are recommended followed by the PIP extension splinting protocol described above. Open reduction internal fixation is recommended in the setting of a central slip avulsion with a large osseous fragment.

For patients with functionally limiting chronic boutonniere deformities, a variety of reconstructive procedures have been described [8, 22–31]. Unfortunately, there is a paucity of literature describing the outcomes of these procedures in younger athletic populations. It is critical to understand the particular skills and activities required of each athlete for participation in their sport before proceeding with operative intervention. Reconstruction procedures can be performed as single or staged procedures with a goal of achieving full passive PIP extension and tendon rebalancing. Extensor tenolysis and PIP joint contracture releases may also be necessary. Arthrodesis is reserved for patients with fixed PIP contractures and painful degenerative changes.

One of the biggest challenges when treating athletes with boutonniere injuries involves return-to-play criteria. While there are no universally accepted guidelines, Lourie describes a helpful mnemonic to guide decision-making [32]. The components of "APPLES" include the following: age (A), position and hand dominance (P), performance level (PL), history of enhancement drugs (E), and in-season versus out-of-season injury (S). While a distance runner may be able to tolerate a PIP extension splint for an acute closed injury, the same may not be true for a high-level soccer goalkeeper or professional pitcher with an injury to the index finger of their throwing hand.

## Pulley injuries

Closed pulley injuries can occur in athletes, most commonly in rock climbers. In a series of 600 injured rock climbers, pulley injuries accounted for 20% of all injuries [33]. Pulley ruptures are most common in the ring and long fingers [33, 34]. Loss of pulley integrity can lead to bowstringing with subsequent losses of both motion and grip strength. While substantial anatomic variability can be present, the pulley system is commonly described as having five annular pulleys and three cruciate pulleys.

Vigouroux et al. studied eight human subjects and found that fingertip forces were highest in the ring and long fingers and that these forces were close to their rupture thresholds [34]. Schoffl et al. described two finger positions frequently used in rock climbing and their relationship to pulley rupture [33]. In the hanging position, the MCP, PIP, and DIP joints are all flexed. In the crimp position, the carpus both supinates and ulnarly deviates with the DIP and MCP joints extending while the PIP joint flexes. This position places increased stress on the ring finger.

While the function between each of the annular pulleys continues to be defined, the A2 and A4 pulleys have classically been described to prevent bowstringing. In a recent cadaveric

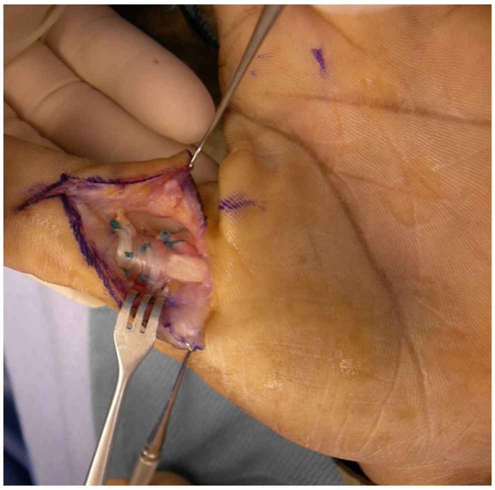

**Fig. 6** Pulley repair using palmaris longus tendon graft

study, Leeflang et al. demonstrated that a 30% excision of A2 resulted in bowstringing and that distal A2 rupture caused more bowstringing than a proximal A2 rupture [35]. Furthermore, they noted that complete A3 excision did not result in bowstringing. In contrast to these findings, Moriya et al. released the entire A2 pulley in seven patients who underwent zone 2 flexor tendon repair and noted an absence of bowstringing in all patients [36]. Moriya et al. also noted an absence of bowstringing after excising A3, C2, and A4 in their series of patients undergoing flexor tendon repair [37].

History, physical examination, and imaging can aid in the diagnosis of closed pulley injuries. Climbers will often report an acute onset of pain during climbing and may recall hearing a "pop." In a series of four professional pitchers, three reported prodromal pain over the middle phalanx prior to sustaining an A4 pulley rupture [38]. Swelling, and occasionally a volar hematoma, will be present in the digit along with tenderness to palpation elicited over the injured pulley. Bowstringing may be present on examination when multiple pulleys are ruptured but may not be present with an isolated rupture [39].

AP and lateral radiographs of the injured digit should be obtained to evaluate for fracture, which should be in the differential diagnosis. At our institution, we utilize dynamic ultrasound when the diagnosis of pulley rupture is suspected. Ultrasound has a sensitivity and specificity of 98 and 100%, respectively [40]. MRI demonstrates similar diagnostic accuracy and can also be utilized in skeletally immature patients where the differential diagnosis includes a non-displaced epiphyseal injury (Fig. 6) [41]. However, it is more expensive and may not be as readily available.

Schoffl proposed a classification system that aids in treatment decision-making: pulley strain (grade I), complete A4 or partial A2 or A3 rupture (grade II), complete rupture of A2 or A3 (grade III), and multiple ruptures or A2 or A3 rupture combined with lumbrical or ligament injury (grade IV) [42].

For partial or isolated complete pulley ruptures (grades I–III), nonsurgical treatment is indicated with rest, taping, edema control, splinting, and functional sport-specific therapy. Multiple complete ruptures (grade IV) are treated surgically. Recent authors have presented their results using a variety of reconstruction techniques. Schoffl et al. reported excellent sport-specific outcomes in five of six climbers who underwent reconstruction of multiple pulley ruptures with a palmaris longus graft [43] (Fig. 6). Bouyer performed 38 reconstructions with extensor retinaculum, noting that 30 patients returned to their previous climbing level and found an association between bowstringing correction and climbing level recovery [44•]. For athletes with multiple pulley ruptures, reconstructive procedures can allow for the return to climbing.

## Conclusions

Due to the infrequent nature of sagittal band ruptures, boutonniere deformities, and pulley ruptures, current treatment is mostly guided by historically established methods, limited case series, and case reports. Nonsurgical treatment remains the mainstay for most injuries and, if employed early, often precludes the need for surgery. Further anatomical and clinical research, including outcome studies, is necessary in guiding treatment algorithms.

#### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Human and animal rights and informed consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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