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Reconstruction of the metacarpophalangeal volar plate with the A1 pulley and 11 cases of proximal interphalangeal/ /metacarpophalangeal volar plate injuries in adolescent age

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Summary

Finger injuries involving the proximal interphalangeal joint (PIPJ) plate are common, but injuries involving the metacarpophalangeal joint (MCPJ) plate are rare. Injury severity is often underappreciated as a "jammed finger". Delayed diagnosis and treatment can have an essential impact on regaining full function. From 2010 to 2021, we dealt with a total of twelve cases of volar plate lesions, eight boys and four girls, from 13 to 16 years of age, eight of them were treated surgically, two with dorsal pinning and two with dorsal block splinting. No significant differences between the patients treated conservatively and operatively were found concerning treatment duration, required physiotherapy and total active motion. No patient developed palmar joint instability, and a painless, stable joint and full grip function was achieved. Surgical treatment of the volar plate injuries is indicated in the case of joint instability, subluxation, persistent swelling, limited range of motion or the presence of dislocation of a bone fragment grade 3–4. Conservative treatment for cases with small or no fragment dislocation is recommended. Untreated volar plate injuries can lead to permanent loss of function, inadequate treatment leads to persistent swelling, instability, and limited range of motion, which are difficult to treat.

Keywords

volar plate injury – reconstruction with A1 pulley – metacarpophalangeal joint – proximal interphalangeal joint – surgical and conservative treatment

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Introduction

Injuries of the volar plate of the metacarpophalangeal joint (MCPJ) of the fingers are rare; injuries of the proximal interphalangeal joint (PIPJ) are common, especially among athletes. Traumatic lesions of the PIPJ/MCPJ volar plate lead to instability and the flexor digitorum profundus (FDP) tethering effects (quadriga phenomenon) that, together with developing a Swan neck deformity, negatively affect the entire grip function of the hand. The deformity is caused by muscle and tendon imbalance due to injury, surgery, and rheumatoid degenerative changes. This is usually only a cosmetic problem until the PIPJ tends to lock in hyperextension and the patient has difficulty initiating finger flexion (Fig. 1,2). The MCPJ of the thumb is particularly vulnerable to injury mainly because of its unprotected position at the base of the proximal phalanx in the space extended force arm. The direction and intensity determine the location and degree of injury to his/her capsuloligamentous apparatus. While hyperabduction forces cause injury to the ulnar collateral ligament (UCL) and volar plate complex, adduction forces cause injury

Fig. 1. Locked hyperextension in a proximal interphalangeal joint volar plate injury.

Fig. 2. A proximal interphalangeal joint volar plate injury after refixation of the volar plate.

Fig. 3. A stable proximal interphalangeal joint volar plate injury suitable for non-operative treatment.

Fig. 4. A stable proximal interphalangeal joint volar plate injury suitable for non-operative treatment.

to the radial collateral ligament (RCL). Isolated hyperextension usually injures the palmar complex, leaving the collateral ligaments relatively intact.

The volar plate avulsion injury fracture is usually caused by a hyperextension force, by a volar or dorsal dislocation of the joint, occasionally by a crush injury and occurs when the middle phalanx is hyperextended up to 70–80° at the time of injury. A longitudinal tear in the accessory collateral ligament can coincide. The bony avulsion nearly always occurs at the distal attachment due to its fibrocartilaginous fusion with bone. The proximal attachments of the volar plate (check reins) are strong and rarely torn [1].

The biomechanics of the volar plate of the PIPJ is characterised by three sequential phases: sliding, elevating, and rolling in the recess. The A3 pulley may be an elevator of the volar plate, triggering the next rolling phase in the recess [2]. Bony abruptions of the volar plate of the PIPJ are essential indicators of the severity of accompanying capsular and ligamentous injuries and assist in determining specific forms of treatment [3].

The volar plate at the MCPJ level does not have a determined and constant length. Still, it does adapt its extension in the longitudinal direction to the joints' excursions, more than doubling in length in an extended position compared to its minimal length in a maximally flexed MCPJ. Criss-crossing fibres perform this throughout the palmar ligament. Distally, the palmar ligament is attached to the base of the proximal phalanx on both sides with no mechanically relevant fixation in the middle. This predominant lateral attachment is additionally stabilised by the proximal section of the phalangoglenoidal ligaments, thus extending the area of osseous fixation. One major force (extension of MCPJ) is splitting the strain over a wide area. This biomechanical principle of restraining extension can be compared to the architecture of Gothic cathedrals or modern architecture bridges. Operative

Fig. 5. An instable proximal interphalangeal joint volar plate injury with large displaced fragment for operative treatment.

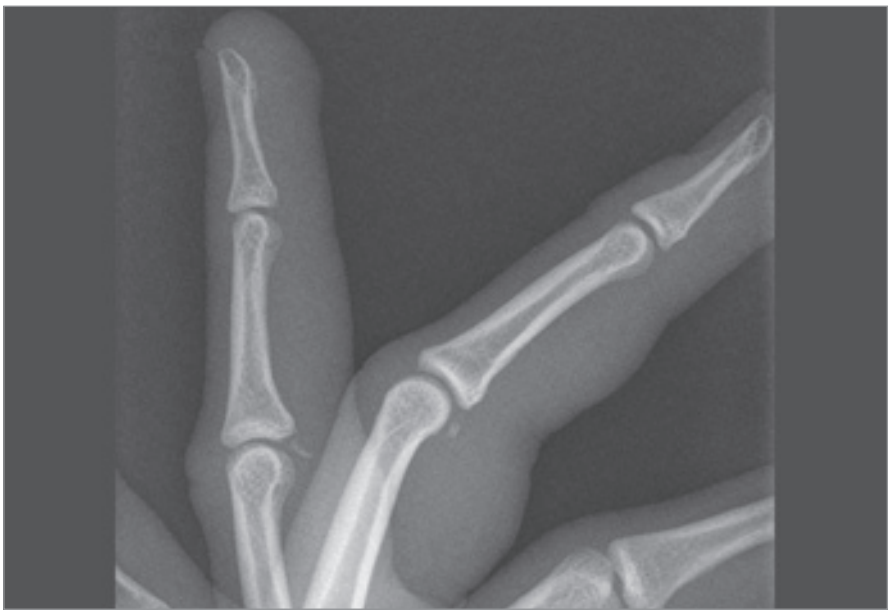

Fig. 6. Instable proximal interphalangeal joint volar plate injury with a large displaced fragment for operative treatment.

treatment in this area should be modified by considering these functional and morphological criteria, thus lowering the frequency of relapse in volar plate surgery [4].

In stable avulsions of collateral ligaments and volar plate with or without involvement of bone, non-operative treatment is preferred (Fig. 3,4). Operative stabilisation is reserved for large displaced bony fragments or complex instabilities (Fig. 5,6). In basal fractures of the middle phalanx, the elimination of joint subluxation and restoration of joint stability is the priority.

If the fragments are too small for fixation with standard implants/screws, they can be fixated with a bone-to-tendon, i. e. fragment-to-ligament "around the bone" like suture with polydioxanone (Fig. 7,8) slightly like that Green [5] used for reinserting the FDP tendon graft to the distal profundus stump, especially in adolescents. Further therapeutic alternatives include refixation of the volar plate (Fig. 2), dynamic distraction fixa-

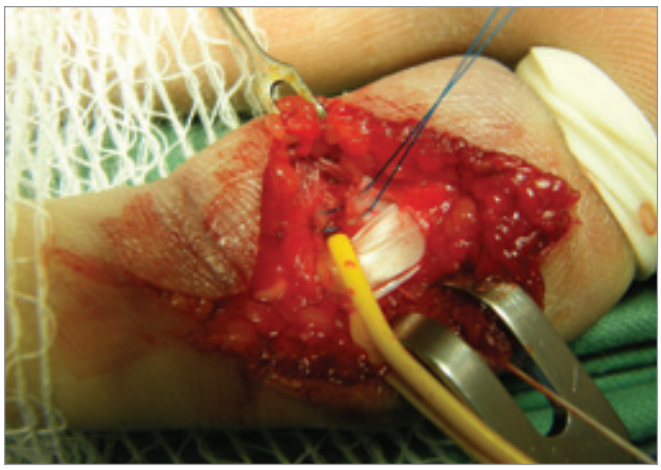

Fig. 7. The fragment-to-ligament "around the bone"-like suture.

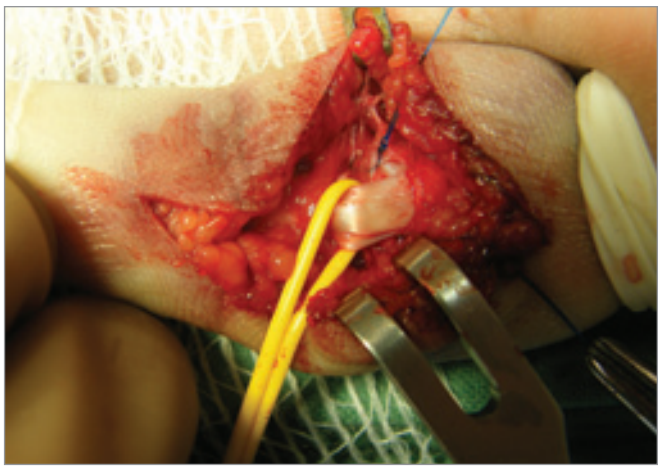

Fig. 8. The fragment-to-ligament "around the bone"-like suture completed.

Tab. 1. Patient with volar plate injury and methods of treatment.

Finger	I.	II.	III.	IV.	V.
MCP left			1 op.		
MCP right	1 op.				
PIP left		1 op.			1 op.
PIP right		1 K/1 op.	1 cons./2 op.	1 cons./1 op.	1K

cons. – conservative therapy – splinting, K – Kirschner wire, MCP – metacarpophalangeal, op.– operative, PIP – proximal interphalangeal

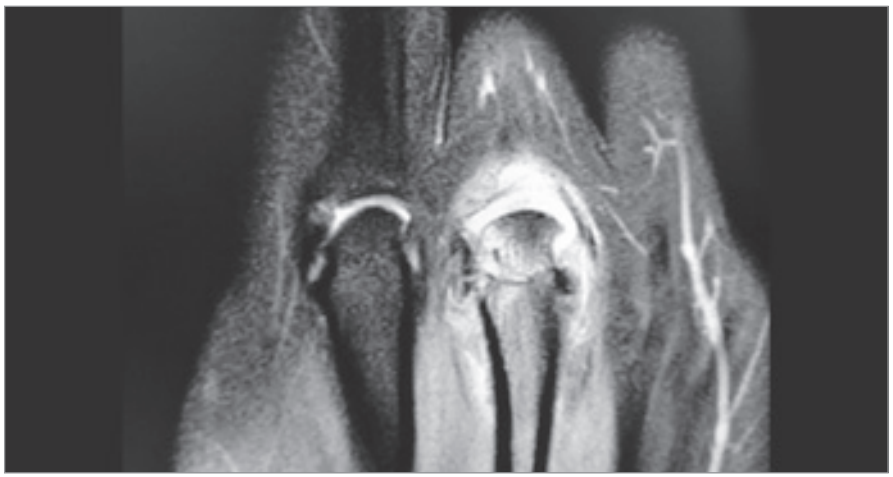

Fig. 10. Preoperative MRI: signs of arthritis and cartilage erosion of the joint surfaces.

tion, percutaneous stuffing and other techniques. An early motion is initiated regardless of the treatment regime.

Undertreatment leads to persistent swelling, instability, and limited range of motion, which are difficult to treat. Contributing factors are unnecessary immobilisation in more than 20° flexion or transfixation by K-wires. For residual limitations, non-operative treatment with physiotherapists and splinting is the first choice [6]. Volar plates are used as a graft source in radial or ulnar collateral ligament reconstruction, pulley reconstruction, and volar plate arthroplasty [7].

Eaton classification of volar plate injuries

- Type 1: avulsion of the volar plate without a fracture or dislocation
- Type 2: complete dorsal dislocation without fracture and avulsion of the volar plate
- Type 3a: Fracture-dislocation with < 40% PIPJ surface with dorsal portion of the collateral ligaments remaining attached to the middle phalanx (stable)
- Type 3b: Fracture-dislocation with > 40% PIPJ surface with little or no ligament remaining attached to the middle phalanx (unstable) [8,9].

Keifhaber-Stern classification of volar plate injuries (modification of Hastings classification)

- Stable: avulsion fracture involving < 30% articular base of the middle phalanx
- Tenuous: avulsion fracture involving 30–50% articular base of the middle phalanx reduces with < 30° of flexion
- Unstable: avulsion fracture involving < 50% articular base of the middle phalanx but requires > 30° flexion to maintain reduction [9,10].

Fig. 9. Preoperative MRI: volar subluxation of the basis of the proximal phalanx.

Materials and methods

From 2010 to 2021, we dealt with twelve cases of volar plate lesions, eight boys and four girls, aged from 13 to 16 years (tab. 1). Eight of them were treated surgically with the reconstruction/replacement of the volar plate, two with K-wire dorsal pinning to the head of the proximal phalanx to prevent hyperextension and two others with dorsal block splinting. Ten patients were treated acutely. Only the patient with the instability of the thumb, which developed gradually throughout 2 weeks after the injury, and the patient with a 4-month-old MCP volar plate lesion of the left third finger were operated on postponed in time. In nine out of twelve cases, the dominant right hand was affected.

MCP III case: reconstruction of the MCP palmar plate with the A1 pulley in an adolescent

A 14-year-old female adolescent presented with a 4-month history of a painful "jammed finger" after a fall on snow on the extended left hand. In a physical

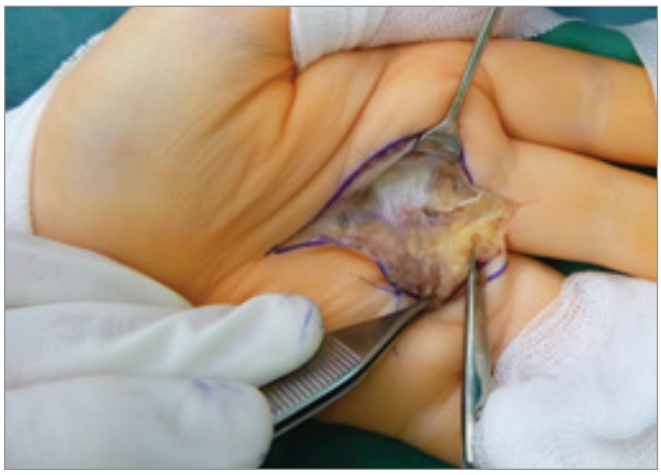

Fig. 11. The metacarpophalangeal joint volar plate entirely dissolved, not suitable for reconstruction.

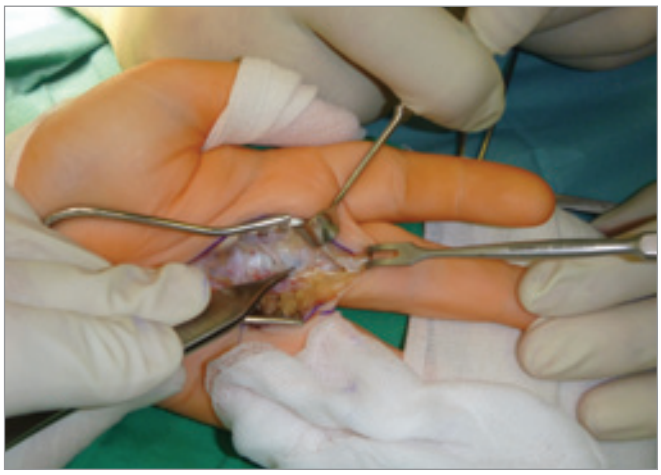

Fig. 12. Unilateral release of the A1 pulley.

Fig. 13. The A1 pulley suture for the replacement of the volar plate, flexor tendons retracted.

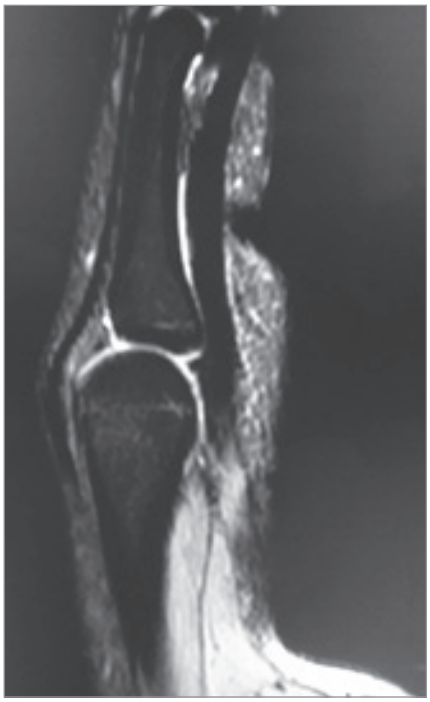

Fig. 14. Postoperative MRI: reposition of the basis of the proximal phalanx.

examination, a painful swelling of the unstable MCPJ of the third finger was present, with difficulty initiating flexion and an inability to perform power grip of the whole hand. The preoperative MRI (Fig. 9,10) demonstrated signs of arthritis, cartilage erosion of the joint surfaces and volar subluxation of the basis of the proximal phalanx, so the decision for operative revision was made.

Intraoperative findings showed that the MCPJ volar plate was dissolved entirely and could not be mobilized and repaired (Fig. 11). For the reconstruction, the A1 pulley was used (Fig. 12,13). The postoperative MRI (Fig. 14) showed a stable reposition, cartilage surface restoration, no signs of bowstringing and within 6 months postoperatively full range painless motion was achieved (Fig. 15,16).

Ten PIPJ cases, one MPCJ thumb case

In the group of further 11 patients, we diagnosed a volar plate injury (Tab. 1). The indication for the operation was the presence of an abruption from the base of the medial phalanx and significant palmar instability of the joint. Intraoperative findings showed that the volar plate was dissolved entirely, but it could be mobilized and repaired in all cases.

Fig. 15. A full range painless motion postoperatively – flexion.

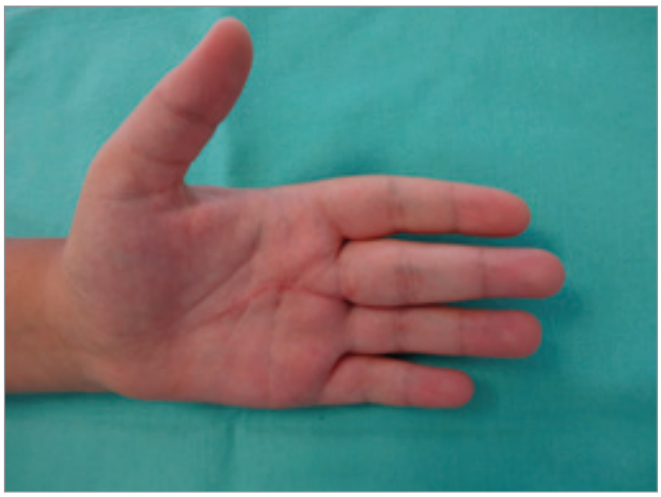

Fig. 16. A full range painless motion postoperatively – extension.

Results

No significant differences between the patients treated conservatively and operatively were found concerning treatment duration, amount of required physiotherapy treatment sessions, total active motion (TAM) and extension deficit in the PIPJ/MCPJ at the end of the treatment, time until hand therapy was started, or the Eaton/Littler diagnosis. After a median of 10 (9–12) weeks of the treatment, ten (83%) patients had excellent results, two (17%) had good results, and none (0%) of the patients had a poor result with a median of 90° (85–120°) TAM in the PIPJ/MCPJ compared with the healthy side. No patient developed palmar joint instability, and a firm and stable PIPJ/MCPJ, without a tendency to hyperextension and complete grip function of the affected finger, was achieved. Minor restrictions on the extension of 15° in PIPJ in a patient with an injury to the little finger and 10° in a patient with an inverted lesion in the area of the MCPJ, treated by replacing the palmar plate with the A1 annular pulley, can be tolerated. The hyperextension was well corrected, and none showed recurrence of the initial deformity even 3–10 years after the reconstruction. The average flexion of the PIPJ was 93° (range = 78–95°), and the average flexion contracture was 3° (range 0–15°). The postoperative radiographs revealed no degenerative changes in 10 PIPJ and 2 MCPJ patients. These favourable results can probably be attributed to the excellent tissue regeneration and remodelling [8] based on the patient's young adolescent age.

Discussion

Lesions of the volar plate are often overlooked, underdiagnosed, underestimated and potentially disabling. As it stabilizes the PIPJ/MCPJ together with collateral ligaments, its untreated injuries lead to their instability and thus negatively affect the entire grip function of the hand. Therefore, a detailed knowledge of anatomy and function is necessary, together with careful physical and imaging examination to diagnose the degree of damage. Abruption of bone fragments grade 3–4, Hintringer may appear along with its lesion [11]. Surgical treatment is indicated in the case of joint instability, subluxation, persistent swelling, limited range of motion or dislocation of a bone fragment grade 3–4.

Conservative treatment for cases with small or no fragment dislocation is recommended for Eaton type I/II [12]. It would be unsuccessful if the fracture fragment, even if small, is much displaced or rotated [13]. The goal is to ensure a painless and stable joint. K-wire dorsal pinning to the head of the proximal phalanx vs. dorsal block splinting [14] is preferable in adolescents because of its reliability. Minor limitations of movement can be tolerated. An examination of joint instability under general/local anesthesia is recommended in case of therapeutic embarrassment. Stabilizing the MCPJ is critical to ensure a pain-free repair and efficient pinch mechanism. The use of an A1 pulley for palmar plate reconstruction at the MCPJ level is a unique procedure since it is technically demanding [15].

Conclusion

Finger injuries involving the proximal interphalangeal joint are common, particularly among athletes. Injury severity is often underappreciated at initial presentation and may be dismissed broadly as a "jammed finger" injury. Delayed diagnosis and treatment of specific injuries can substantially impact the patient's chance of regaining full function. Central slip and PIPJ volar plate injuries are frequently encountered injuries that, if left untreated, can lead to permanent loss of function.

Despite the differing mechanisms of these two pathologies, volar plate hy-

perextension injuries often present with a PIPJ flexion contracture and mild distal interphalangeal joint hyperextension deformity. This is like a boutonnière deformity seen after an injury to the central slip and, thus, has been referred to as a "pseudo-boutonnière" deformity. Distinguishing these two diagnoses is essential, as treatment differs and highlights the importance of thoroughly understanding the anatomy and relevant clinical applications when evaluating PIPJ injuries [16].

Disclosure

The authors have no conflicts of interest to disclose. The authors declare that this study has received no financial support. All procedures performed in this study involving human participants followed the ethical standards of the institutional and/or national research committee and with the Helsinki Declaration and its later amendments or comparable ethical standards.

Roles of authors

Roman Bánsky – author of the manuscript, Jaroslav Olexík – data collection, Magdalina Krayinina – data analysis, Štefan Estergályos – graphics

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