



Correction of Severe Crossover Toe Deformity By Plantar Plate Tenodesis, Arthroscopic Release of Lumbrical and Plication of Lateral Capsuloligamentous Complex

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Abstract: Plantar plate deficiency is the major cause of instability of the metatarsophalangeal joint, and plantar plate tenodesis can provide dynamic stabilization of the plantar plate. In case of crossover toe deformity, incorporation of arthroscopic release of the medial capsuloligamentous complex and the lumbrical tendon can eliminate the medial deforming force. However, in case of severe deformity, the lateral capsuloligamentous complex is attenuated. The purpose of this Technical Note is to incorporate the technique of arthroscopic plication of the lateral capsuloligamentous complex into the technique of plantar plate tenodesis and arthroscopic release of the medial capsuloligamentous complex and the lumbrical tendon.

Crossover deformity of the second toe is a common forefoot deformity. Most commonly, it is caused by plantar plate insufficiency leading to instability of the metatarsophalangeal (MTP) joint.^{1,2} As the joint instability deteriorates and the joint subluxates dorsally, the axis of pull of the interossei shifts dorsal to the center of rotation of the MTP joint and becomes an ineffective flexor of the joint. The lumbrical is tethered at the medial side of the joint by the deep metatarsal ligament and becomes a deforming force for the development of crossover toe deformity.^{3,4} As the disease deteriorates, the MTP joint can be dislocated with attenuation or rupture of the lateral capsuloligamentous complex.

Conservative treatment including the toe splint is usually ineffective to control the deformity and its symptoms, and surgical treatment is indicated for symptom control.⁵ Surgical treatments of this deformity include soft tissue balancing procedures to stabilize the MTPJ (plantar plate repair, tendon release or transfer, periarticular soft-tissue release) or bony procedures (metatarsal/phalangeal osteotomy, arthrodesis and excisional arthroplasty) and even toe amputation.⁶ The Girdlestone-Taylor flexor-to-extensor tendon transfer is an effective method to stabilize the sagittal alignment of the MTP joint, but it may not be able to restore a normal coronal alignment of the MTP joint in crossover toe deformity and post-operative toe stiffness is common.^{2,7-10} Because the primary pathology is the plantar plate deficiency, plantar plate repair is a logical surgical treatment choice.¹¹ Plantar plate repair is as effective as tendon transfer in stabilization of the MTP joint with less postoperative stiffness and discomfort.⁸ Surgical options of plantar plate repair include primary repair with or without the use of suture anchor or repair by distal advancement of the plate to the base of the proximal phalanx through bone tunnels via the plantar or dorsal approaches.^{2,3,6,10,12-20} However, open plantar plate repair requires extensive soft tissue dissection which may induce periarticular fibrosis. Plantar plate tenodesis, an arthroscopically assisted dynamic repair of the plantar plate, can

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Table 1. Indications and Contraindications of Correction of Severe Crossover Toe Deformity By Plantar Plate Tenodesis, Arthroscopic Release of Lumbrical, and Plication of Lateral Capsuloligamentous Complex

Indication	Symptomatic severe crossover toe deformity that is recalcitrant to conservative treatment.
Contraindications	The second metatarsophalangeal joint is degenerated or destructed There is Morton neuroma at the lateral side of the deformed toe Fixed dislocation of the second MTP joint The deformity is caused by bony deformities of the metatarsal or the proximal phalanx
	MTP, metatarsophalangeal.

stabilize the attenuated or ruptured plantar plate through suturing the plantar plate and fibrous flexor tendon sheath to the long extensor tendon of the second toe.^{4,5,17-19} This minimally invasive technique allows magnified arthroscopic visualization of the operative field without the need for extensive soft tissue dissection or metatarsal osteotomy. Recently, the technique of arthroscopic release of lumbrical tendon has been incorporated into the technique of plantar plate tenodesis.¹¹ This can eliminate the deforming force of the tethered lumbrical. In severe crossover toe deformity, in addition to the deforming force of the tethered lumbrical, the lateral capsuloligamentous complex of the MTP joint is attenuated. In this Technical Note, we report a modification of the plantar plate tenodesis and arthroscopic lumbrical release and incorporate arthroscopic plication of the attenuated lateral capsuloligamentous complex into the technique. It is indicated for symptomatic severe crossover toe deformity that is recalcitrant to conservative treatment.²¹ The procedure is still feasible in case of dislocated second MTP joint if the dislocation is reducible by the closed method. It is contraindicated if the MTP joint is degenerated or destructed, or there is Morton neuroma at the lateral side of the deformed toe, fixed dislocation of the second MTP joint, or the deformity is caused by bony deformities of the metatarsal or the proximal phalanx (Table 1).

Technique

Preoperative assessment and Patient Positioning

Preoperative standing radiograph of the foot is useful to document the severity of the deformity, the presence of any dislocation of the second MTP joint, degeneration or destruction of the involved MTP joint or the presence of any bone deformity of the metatarsal or proximal phalanx. There should not be any clinical evidence of Morton's neuroma of the second toe web.

The patient is in the supine position with a thigh tourniquet to provide a bloodless operative field. A 1.9 mm 30° arthroscope (Henke Sass Wolf GmbH) is

used for this procedure. Fluid inflow is driven by gravity, and no arthro-pump is used. Continuous toe traction is not needed.

Portal Placement and Second Metatarsophalangeal Arthroscopy

The portals used are the standard dorsomedial and dorsolateral portals of second MTP arthroscopy, which are located at the MTP joint level and are at the medial and lateral side of the long extensor tendon respectively. Skin incisions of 3 to 4 mm are made at the portal sites. The subcutaneous tissue is bluntly dissected down to the joint capsule by a hemostat and the dorsal capsule is perforated by the tip of the hemostat. The MTP joint is examined arthroscopically for the integrity of the plantar plate, the status of the articular cartilage and the presence of synovitis (Fig 1). Arthroscopic synovectomy is performed with an arthroscopic shaver (Smith and Nephew) if synovitis is present.¹¹ The dorsal capsule is stripped from the metatarsal neck by a small periosteal elevator via the portals.

Release of Medial Capsuloligamentous Complex

The dorsolateral portal is the viewing portal, and the dorsomedial portal is the working portal. The medial capsuloligamentous complex (medial capsule and medial proper collateral ligament) is released by means of a SuperCut scissors (Stille, Lombard, IL) (Fig 2).

Release of Lumbrical Tendon

The dorsolateral portal is the viewing portal and the dorsomedial portal is the working portal. The lumbrical tendon can be seen after complete release of the

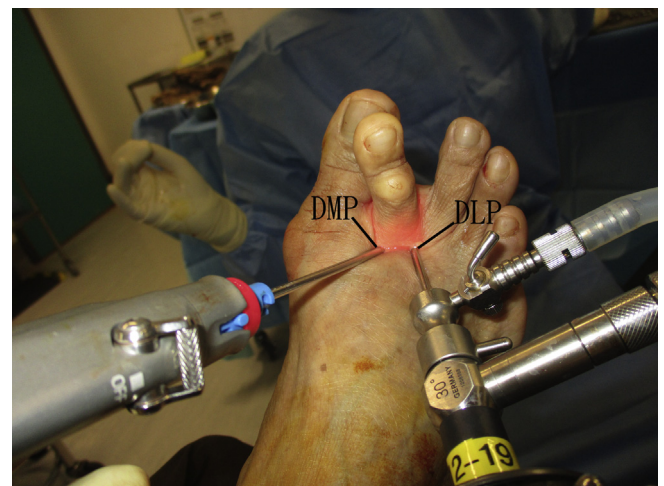


Fig 1. Correction of severe crossover toe deformity of the right second toe by plantar plate tenodesis, arthroscopic release of lumbrical and plication of lateral capsuloligamentous complex. The patient is in the supine position. Second metatarsophalangeal arthroscopy is performed via the dorsomedial and dorsolateral portals. DMP, dorsomedial portal; DLP, dorsolateral portal.

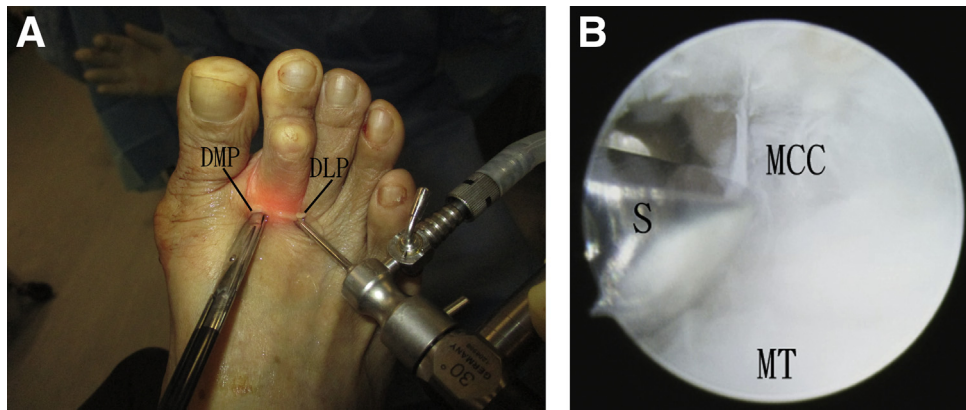


Fig 2. Correction of severe crossover toe deformity of the right second toe by plantar plate tenodesis, arthroscopic release of lumbrical and plication of lateral capsuloligamentous complex. The patient is in supine position. The dorsolateral portal is the viewing portal and the dorsomedial portal is the working portal. (A) Clinical photo shows that the scissars is inserted into the dorsomedial portal. (B) Arthroscopic view shows that the medial capsule together with the medial proper collateral ligament is released by the scissars. DMP, dorsomedial portal; DLP, dorsolateral portal; S, scissars; MCC, medial capsuloligamentous complex; MT, metatarsal head.

medial capsuloligamentous complex. The lumbrical tendon can then be identified and released with the scissars (Fig 3).

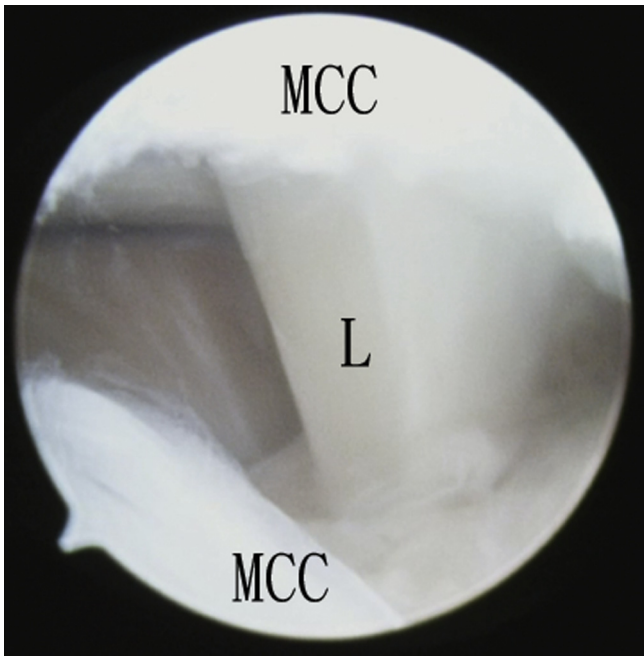


Fig 3. Correction of severe crossover toe deformity of the right second toe by plantar plate tenodesis, arthroscopic release of lumbrical and plication of lateral capsuloligamentous complex. The patient is in the supine position. The dorsolateral portal is the viewing portal, and the dorsomedial portal is the working portal. The lumbrical tendon can be seen after complete release of the medial capsuloligamentous complex. The lumbrical tendon can then be identified and released with the scissars. MCC, medial capsuloligamentous complex; L, lumbrical tendon.

Anchoring Lateral Part of Plantar Plate and Plication of the Lateral Capsuloligamentous Complex

The dorsomedial portal is the viewing portal and the dorsolateral portal is the working portal. The dorsolateral portal incision is retracted laterally. A straight-eyed needle (FavorMed, Ningbo, China) loaded with a no. 1 PDS suture (Ethicon, Johnson & Johnson, Cincinnati, OH) is passed through the dorsal corner of the lateral capsuloligamentous complex and is then entered into the second MTP joint. With further advancement of the needle in the lateral gutter of the MTP joint, the needle pierces the lateral edge of the plantar plate. The needle and the suture pass through the lateral edge of the plantar plate close to its phalangeal insertion, the fibrous flexor tendon sheath, and the plantar skin. It is important to make sure the sutures are staying in the lateral gutter and not across the joint proper to avoid subsequent scratching of the cartilage by the suture. A 1 cm proximal incision is made at the dorsal side of diaphysis of the second metatarsal. The suture is retrieved from the plantar surface of the flexor fibrous tendon sheath to the proximal incision by a curved hemostat along the lateral surface of the metatarsal. The suture is tensioned to facilitate catching of the suture by the hemostat. The other limb of the suture passes through the dorsal corner of the lateral capsuloligamentous complex, the lateral edge of the plantar plate, fibrous flexor tendon sheath, and the plantar skin by means of the straight-eyed needle via the dorsolateral portal. A suture loop is maintained at the dorsolateral portal to allow tensioning of the suture during retrieval of the suture limb back to the proximal incision. This helps the hemostat to catch the suture at the plantar surface of the fibrous flexor tendon sheath. The lateral gutter is obliterated, and the lateral capsuloligamentous complex is plicated by pulling

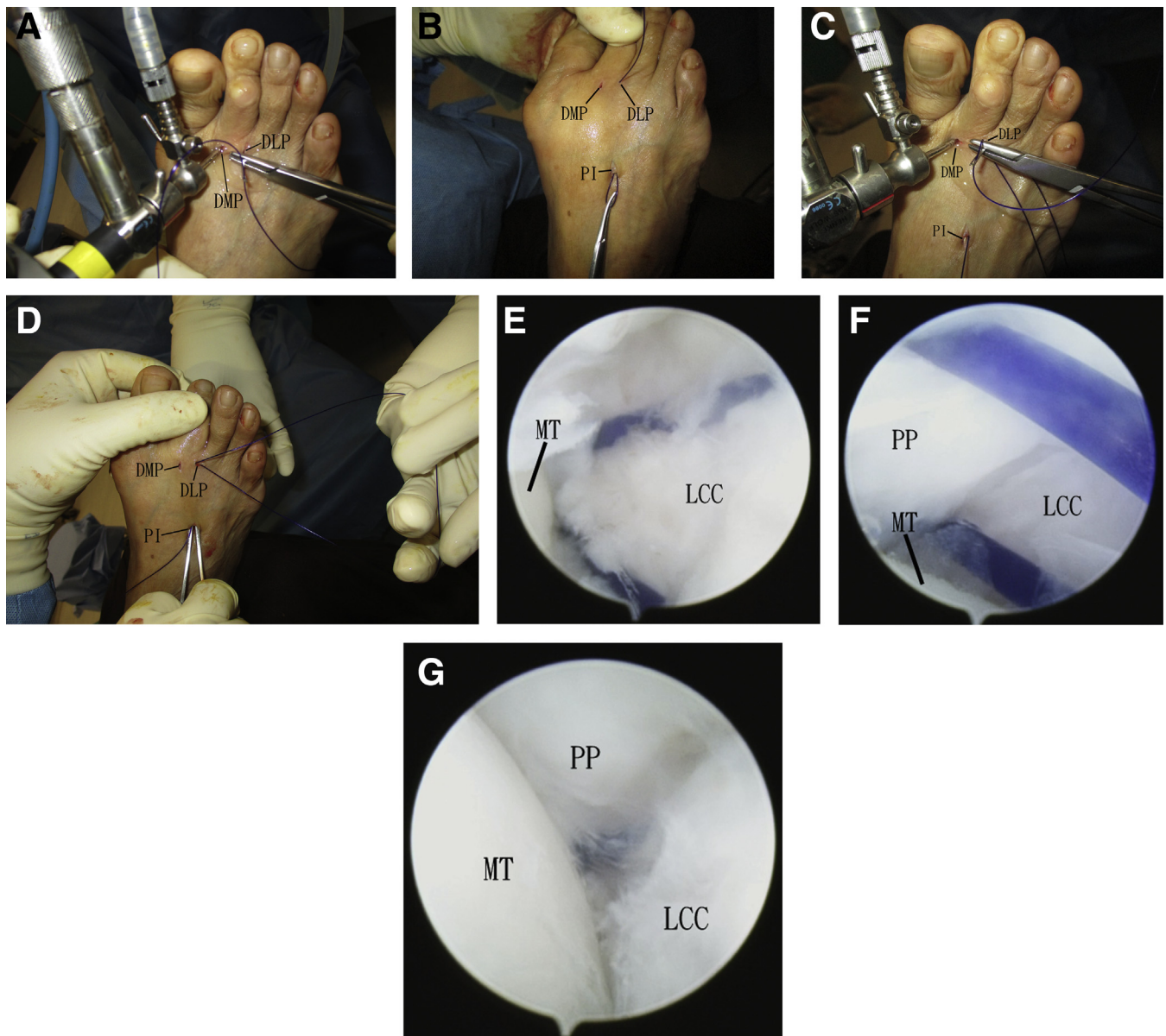
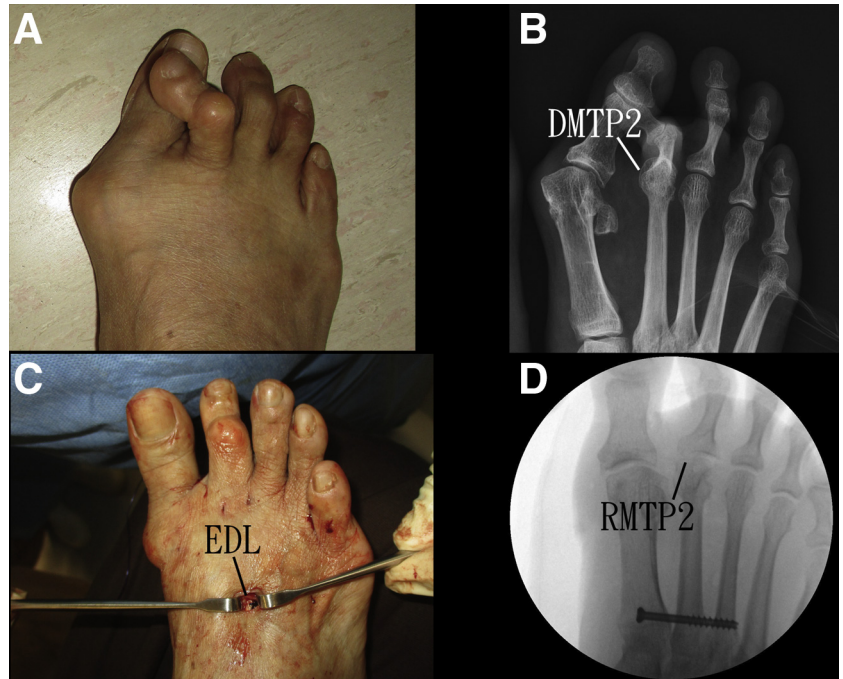


Fig 4. Correction of severe crossover toe deformity of the right second toe by plantar plate tenodesis, arthroscopic release of lumbrical and plication of lateral capsuloligamentous complex. The patient is in the supine position. The dorsomedial portal is the viewing portal and the dorsolateral portal is the working portal. (A) The dorsolateral portal incision is retracted laterally. A straight-eyed needle loaded with a no. 1 PDS suture is passed through dorsal corner of the lateral capsuloligamentous complex and then entered into the second MTP joint. With further advancement of the needle in the lateral gutter of the MTP joint, the needle pierces the lateral edge of the plantar plate. The needle and the suture pass through the lateral edge of the plantar plate close to its phalangeal insertion, the fibrous flexor tendon sheath and the plantar skin. It is important to make sure the sutures are staying in the lateral gutter and not across the joint proper to avoid subsequent scratching of the cartilage by the suture. (B) A 1 cm proximal incision is made at the dorsal side of diaphysis of the second metatarsal. The suture is retrieved from the plantar surface of the flexor fibrous tendon sheath to the proximal incision by a curved hemostat along the lateral surface of the metatarsal. The suture is tensioned to facilitate catching of the suture by the hemostat. (C) The other limb of the suture passes through the dorsal corner of the lateral capsuloligamentous complex, the lateral edge of the plantar plate, fibrous flexor tendon sheath and the plantar skin by means of the straight eyed needle via the dorsolateral portal. (D) A suture loop is maintained at the dorsolateral portal in order to allow tensioning of the suture during retrieval of the suture limb back to the proximal incision. This helps the hemostat to catch the suture at the plantar surface of the fibrous flexor tendon sheath. (E) Arthroscopic view shows that the suture anchors the lateral capsuloligamentous complex and stays at the lateral gutter of the metatarsophalangeal joint. (F) Arthroscopic view shows that the suture limbs pass through the lateral edge of the plantar plate. (G) The lateral gutter is obliterated, and the lateral capsuloligamentous complex is plicated by pulling the suture. DMP, dorsomedial portal; DLP, dorsolateral portal; PI, proximal incision; LCC, lateral capsuloligamentous complex; MT, metatarsal head; PP, plantar plate.

Fig 5. Correction of severe crossover toe deformity of the right second toe by plantar plate tenodesis, arthroscopic release of lumbrical and plication of lateral capsuloligamentous complex. The patient is in the supine position. (A) Preoperative clinical photograph of the illustrated case shows the crossover second toe. (B) Preoperative radiograph of the illustrated case shows dislocation of the second metatarsophalangeal joint. (C) Clinical photo shows that correction of the crossover toe deformity is completed by sewing the sutures under tension to the extensor digitorum longus tendon to the second toe. (D) Fluoroscopic view after the procedure shows that the crossover toe deformity is corrected and the second metatarsophalangeal joint is reduced. The hallux valgus deformity is corrected by endoscopic distal soft tissue procedure. EDL, extensor digitorum longus tendon; DMTP2, dislocated second metatarsophalangeal joint; RMTP2, reduced second metatarsophalangeal joint.



the suture (Fig 4). The procedure is repeated with another no. 1 PDS suture. The crossover toe deformity can be corrected by pulling the sutures.

Correction of the Crossover Toe Deformity

The crossover toe is slightly overcorrected by 20° plantarflexion and 20° abduction of the MTP joint. The sutures are sewed under tension to the extensor

digitorum longus (EDL) tendon to the second toe to complete the correction. If the EDL tendon distal to the sew point is still tight, distal EDL tenotomy can be performed at the portal incisions (Fig 5, Video 1, Table 2). Any concomitant hallux valgus deformity will be corrected under arthroscopic assistance.^{22,23} After surgery, bulky dressing is applied to the operated foot for 2 weeks. The operated lesser toe is allowed free mobilization. The patient is advised for non-weightbearing for 2 weeks and then weightbearing walking as tolerated with wooden-based sandal for another 4 weeks before resuming normal shoe wear.⁵

Table 2. Pearls and Pitfalls of Correction of Severe Crossover Toe Deformity by Plantar Plate Tenodesis, Arthroscopic Release of Lumbrical, and Plication of Lateral Capsuloligamentous Complex

Pearls

- The release of the medial capsuloligamentous complex, lumbrical and dorsal capsule should be completed.
- The needle should pierce the dorsal corner of lateral capsuloligamentous complex and the lateral edge of the plantar plate close to its phalangeal insertion.
- The sutures should be at the lateral gutter of the metatarsophalangeal joint.
- The hemostat should be inserted along the lateral side of the metatarsal and no soft tissue should be trapped between the hemostat and the metatarsal.
- The suture is retrieved from the plantar surface of the flexor tendon sheath so that the tendon sheath and the plantar plate are incorporated in the tenodesis construct.

Pitfalls

- If the suture passes through the plantar plate at point medial to its lateral edge, the suture will remain at the metatarsophalangeal joint proper and scratch the articular cartilage.
- Leaving the suture segment that has been weakened by previous clamping in the final suture construct may predispose pre-mature suture failure.
- Using large sized eyed cutting needle to sew the sutures to the extensor tendon may predispose longitudinal tear of the tendon.

Discussion

In crossover toe deformity, the plantar plate is attenuated, deformed and displaced dorsomedially and

Table 3. Advantages and risks of correction of severe crossover toe deformity by plantar plate tenodesis, arthroscopic release of lumbrical and plication of lateral capsuloligamentous complex

Advantages

- Complete soft tissue balance around the metatarsophalangeal joint
- Precise placement of the plantar plate suture
- Minimal soft tissue dissection
- Avoidance of plantar wound
- Preserved tendons of the toes
- Sophisticated instruments are not needed.

Risks

- Injury to the articular cartilage
- Injury to the interdigital nerve.
- Recurred or residual deformity
- Postoperative toe stiffness

the fibrous tendon sheath and the flexor tendons are medially displaced.²⁴ Just stabilize the plantar plate in the sagittal plane may not be good enough. The medially displaced plantar plate, fibrous tendon sheath, and the flexor tendons should be reduced to restore normal flexor force vector. Plantar plate tenodesis provides corrective force to pull back the plantar plate and the flexor tendons to the normal position.^{4,5} As the plantar plate sutures are tied to the EDL tendon, the pull of EDL is redirected plantarward to stabilize the plantar plate and the fibrous flexor tendon sheath. The tension of the EDL distal to the sutures is relieved. If there is residual tension at the EDL tendon distal to the sew point, as in case of severe crossover toe deformity, distal EDL tenotomy can be performed and all the pulling force of EDL will be transmitted plantarly to stabilize the plantar plate. This technique is still feasible even in case of massive or complicated tear or the quality of the tissue is poor as the fibrous tendon sheath is incorporated into the construct.^{5,24} This, together with the release of the dorsal capsule, medial capsuloligamentous complex, and lumbrical, can restore the soft tissue balance around the MTP joint in most of the case and the MTP joint can be reduced and the interosseous tendons become plantar to the axis of rotation of metatarsal head and the intrinsic minus toe will be corrected.¹⁹ In case of severe deformity, the lateral capsuloligamentous complex is attenuated, and we believe that lateral plication can further improve the correction. However, as the orientation of lateral plication sutures in our technique is not along the axis of the proper or accessory lateral collateral ligament, there may be increased risk of postoperative toe stiffness.

The advantages of this technique include complete soft tissue balance around the MTP joint, precise placement of the suture to the plantar plate under arthroscopic guidance, minimal soft tissue dissection, avoidance of plantar wound, tendons of the toes can be preserved, and sophisticated instruments are not needed. The potential risks of this technique include injury to the articular cartilage, injury to the interdigital nerve, recurred or residual deformity, and postoperative toe stiffness (Table 3). This is technically demanding and should be reserved for the experienced foot and ankle arthroscopists.

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