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Lambda (λ) repair: a novel repair technique for chronic Boutonnière deformity

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CONFLICTS OF INTEREST AND SOURCE OF FUNDING

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SUMMARY

Correction of a Boutonnière deformity is one of the most demanding challenges in hand surgery. Usually, surgical interventions are considered when functional use of the finger cannot be obtained after intense hand therapy.

Herein, we introduce our newly described Lambda (λ) repair which is an easy to learn, straightforward surgical technique. The method involves an end-to-side tenorrhaphy of the lateral bands resembling the Greek letter λ.

Patients who underwent a λ repair were retrospectively evaluated with pre- and postoperative measurements of PIP joint movement. We included four patients (2 male, 2 female, median age 35.5 years) with a median follow-up period of 9.1 months. Three patients underwent λ repairs for isolated Boutonnière deformities and one patient received a vascularized free toe transfer combined with a λ repair. The preoperative average PIP joint extension lag or deficit was 28.75°and could be reduced to 15°. Preoperative average PIP joint active flexion was 60° which was also improved to 88.75°. No complications were observed.

The λ repair is a new tool in the reconstruction of Boutonnière deformity, further expanding the armamentarium of hand surgeons.

THE LAMBDA (λ) TECHNIQUE

Boutonnière deformity is a challenging problem to hand surgeons. Rehabilitation is usually recommended for cases without fixed contracture of finger joints. However, surgery must be considered once the functional use of fingers cannot be obtained after hand therapy within six months. Several surgical techniques have been proposed to correct the extensor mechanism after central slip injury [1-10]. However, most of the techniques cannot address all conditions of extensor tendon injuries in zone 3 and deficits in the PIP flexion may occur.

Here, we introduce a novel surgical technique to improve treatment outcome. In brief, a tenolysis of the extensor tendon is followed by end-to-side tenorrhaphy of the lateral bands (Online supplementary material 1). Given the appearance of the end result and resemblance with the letter of the Greek alphabet we named this new technique the lambda (λ) repair.

A curvilinear incision was made on the dorsal aspect of the PIP joint with subsequent exploration of the extensor apparatus. Firstly, tenolysis of the extensor tendon from the zone 1 to 5, including central slip and lateral bands (Online supplementary material 2A and B), transection of transverse retinaculum ligaments and the extensor hood and sling when necessary, was performed. If awake, patients were asked to flex and extend the PIP joint. In case lateral bands did not glide dorsally to extend the PIP joint, a λ repair was performed. One slip of the lateral band was transected from the other at zone 1 (Online supplementary material 2C an D). The divided lateral band was crossed over the proximal third of the middle phalanx (Online supplementary material 2E). Patients were asked to extend and flex the PIP joint to check gliding of the lateral bands. Under general anesthesia the PIP joint was flexed and extended passively to observe the movement of the lateral bands. The location which ensured the gliding movement of the lateral bands dorsally and laterally to the PIP joint during extension and flexion was deemed the most suitable location for the λ repair. A stab incision was made with a no. 11 blade at the location of the intact lateral band and the divided lateral band was interwoven and sutured by two interrupted PDS 4/0 sutures (Online supplementary material 2E – G). After the repair, motion of the PIP joint was reevaluated (Fig. 1 and Online supplementary material 2H). If the lateral bands did not glide properly, the location and tension of the λ repair were re-adjusted accordingly. After careful hemostasis, the wounds were closed without drains by interrupted nylon 4/0 sutures. All of the patients received an immediate postoperative intense rehabilitation program

with the application of an orthosis to keep PIP and DIP joints in full extension for a total of six weeks accompanied by exercises. In the first week after surgery early active short arc motion was performed [11]. During the first four weeks the program consisted of ten repetitions hourly with wrist flexion 30° and MP slight flexion relative to the adjacent MCP joints to facilitate involved finger PIP and DIP extension, less than 30° of PIP flexion and a simultaneous 25° of DIP flexion. Lumbrical and interosseous muscles isometric contraction is encouraged with gutter orthosis in the first 4 weeks. If no lag develops, the degree of PIP flexion was gradually increased by 10° – 20° every week after four weeks post-operative. Additionally, night splinting was encouraged if an extension lag was observed six weeks postoperatively.

Retrospective analysis of prospectively collected data was performed which included patients suffering from chronic Boutonnière deformity (Table 1) and which were operated by the senior author (YTL) after obtaining written consent and approval by the institutional review board (IRB number: 202200319B0).

The patients were assessed preoperatively, including functional measurements of the proximal interphalangeal (PIP) joint including extension lag and flexion. Only patients with full passive range of motion (pROM) of the PIP joint were considered eligible for surgery. Postoperative assessment included measurements of active range of motion (aROM) at metacarpophalangeal (MCP), PIP and distal interphalangeal (DIP) joint levels (Table 1).

Three of the four patients (patient 1, 2 and 4) were operated under wide awake local anesthesia no tourniquet (WALANT). One patient (patient 3) was treated under general anesthesia with the use of a tourniquet.

In total, λ repair was performed in four cases (details in Table 1). Patient 1, 2 and 4 underwent λ repair for isolated Boutonniere deformities, in patient 3 the λ repair was performed

alongside a vascularized free toe transfer (Online supplementary material 3 and 4). The average preoperative PIP joint extension deficit was 28.75° (range, 0° – 65°) which was postoperatively reduced to 15° (range, -25° – 55°). Preoperative average PIP joint active flexion was 60° (range, 0° – 80°) which was postoperatively improved to 88.75° (range, 70° – 100°). Postoperative flexion of MCP and DIP was 87.5° (range, 80° - 95°) and 30° respectively (range, 20 – 35°). Postoperative extension of MCP and DIP was 0° (range, 0°) and 0° (range, 0 – 15°) respectively. Clinical documentation of patient #4 can be appreciated in online supplementary material 5. No complications were observed nor reported.

DISCUSSION

The extension of the interphalangeal joints of the finger is orchestrated by a delicate interplay between extrinsic and intrinsic extensors. Extension of the PIP joint is controlled by the central slip and lateral bands of the extensors. Under physiological conditions with intact extensors, the lateral bands at PIP joint level will displace volarly in flexion and return to the dorsum of the joint in extension.

Boutonnière deformity is caused by damage to the central slip with secondary volar migration of the lateral bands. Demonstrated by Schultz *et al.* the lateral bands are unable to return to the midline when a proximally directed longitudinal force is applied[8]. Balance of the tendon length and the transmitted force between the central slip and the lateral bands is critical for flexion and extension of the PIP and DIP joints. The gliding ability of the lateral bands on the PIP joint longitudinally and volar-dorsally are both important for proper motion. When the extensor mechanism is injured at PIP joint level, both extension and flexion can be affected.

Boutonnière deformities are challenging to repair because most of the chronic extensor tendon injuries in zone 3 will present with fibrosis and adhesion between the central slip and lateral bands.

Multiple techniques have been described to correct this deformity[1,3,5,12]. However, most of them are not able to address extensor tendon injuries of zone 3 and reported flexion deficits. This is mainly due to the fact that the intrinsic and extrinsic extensor tendons relax and migrate distally when the fingers are flexed. Compared to the existing techniques, the λ repair allows the lateral bands to glide laterally on the PIP joint facilitating flexion of both PIP and DIP joints. During finger extension the extensor muscles pull the lateral bands proximally, narrowing the angle between lateral bands and centralizing them over the PIP joint resulting in an improvement of PIP and DIP extension.

In conclusion, our proposed λ repair is an effective, easy to learn new technique to correct a chronic Boutonnière deformity as well as addressing zone 3 of the extensor apparatus.

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FIGURE, TABLE AND ONLINE SUPPLEMENTARY MATERIAL LEGENDS

Figure 1. Schematic of surgical technique (**A**) and step by step biomechanical function after λ repair (**B – D**). (**B**) Finger flexion causes extensors to relax and move distally. (**C**) With further flexion, lateral bands move more distally and volarly. (**D**) Finger extension causes lateral bands to retract and move dorsally.

Table 1. Patient demographics, preoperative and postoperative function.

Online Supplementary Material 1. Video demonstrating the surgical technique.

Online Supplementary Material 2. Intraoperative photographs demonstrating the surgical technique step by step.

Online Supplementary Material 3. Pre-, intra- and postoperative photographs demonstrating patient case #3.

Online Supplementary Material 4. Video demonstrating intraoperative passive motion testing of patient case #3.

Online Supplementary Material 5. Photographs of patient case #4 and function of the second digit.

Table 1. Patient demographics, preoperative and postoperative function.

Case No.	Age	Gender	Procedure	Preoperative extension lag	Preoperative flexion	Postoperative aROM MCP	Postoperative aROM PIP	Postoperative aROM DIP	Follow-up (mo)
1	39	F	λ repair 3rd digit right hand	65°	80°	0 - 95°	10 - 90°	0 - 20°	3.2
2	33	M	λ repair 3rd digit left hand	30°	80°	0 - 85°	20 - 95°	0 - 25°	11.3
3	14	F	Combination of vascularized toe transfer and λ repair of 3rd digit left hand	0°	0°	0 - 80°	25 - 70°	0 - 35°	4.2
4	38	M	λ repair 2nd digit left hand	20°	80°	0 - 90°	0 - 100°	15 - 50°	17.6

λ, lambda

aROM, active range of motion

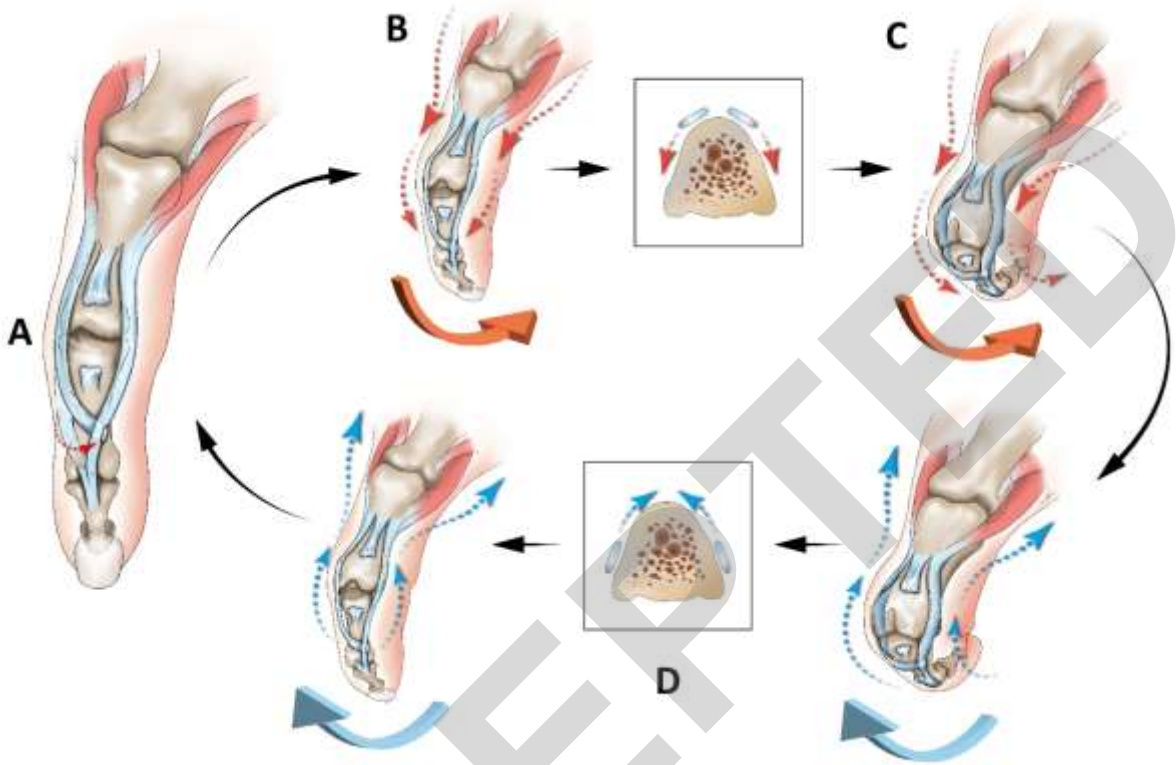
MCP, metacarpal

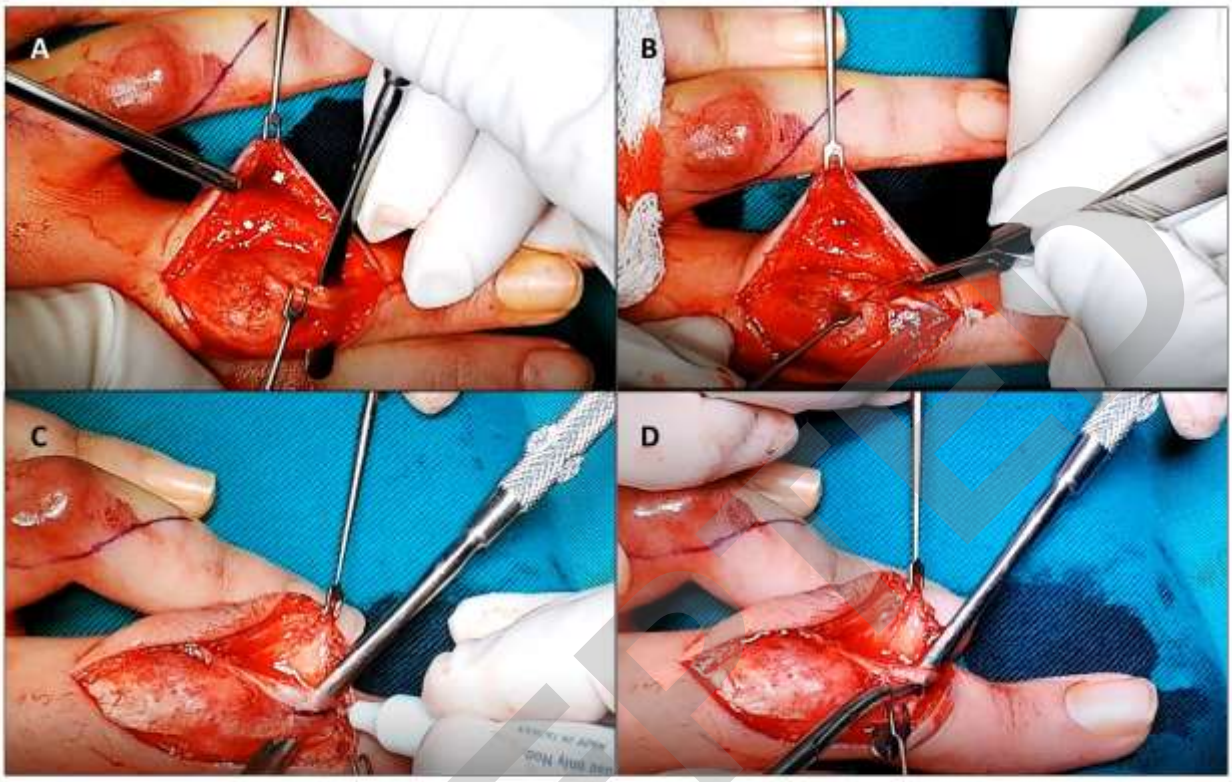
PIP, proximal interphalangeal

DIP, distal interphalangeal

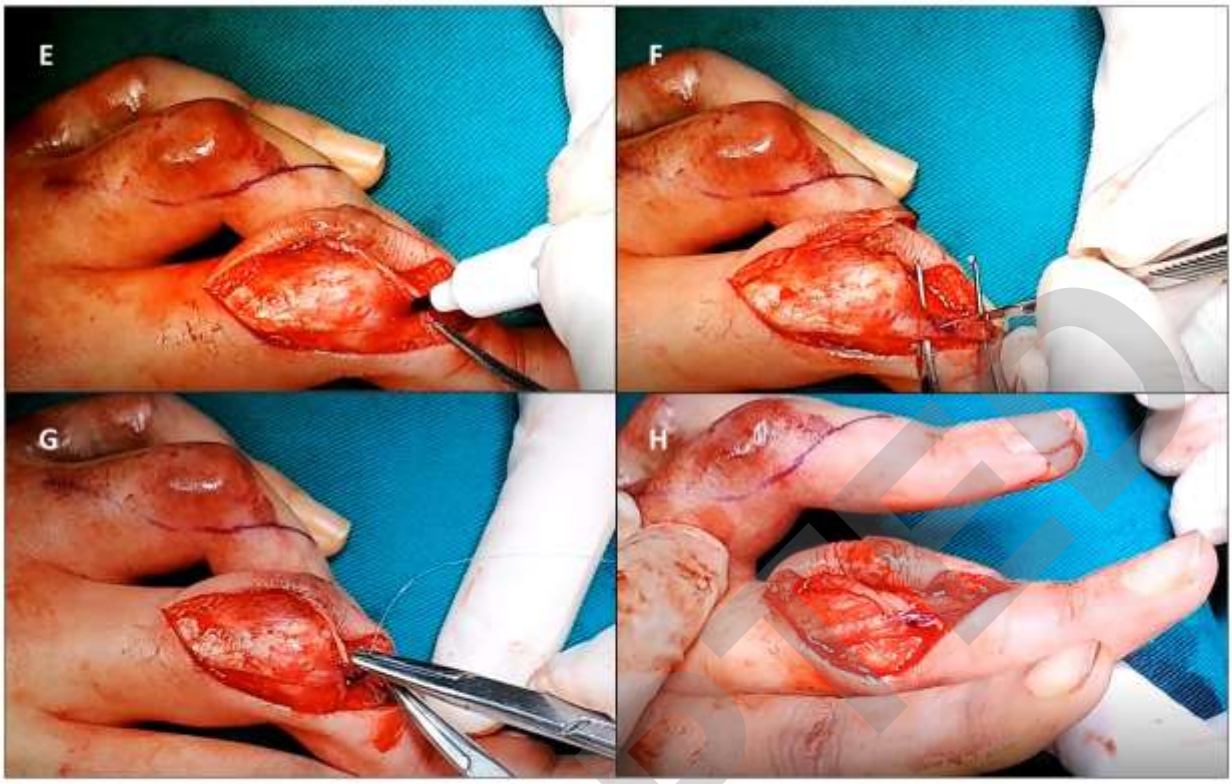
mo, months

Figure 1

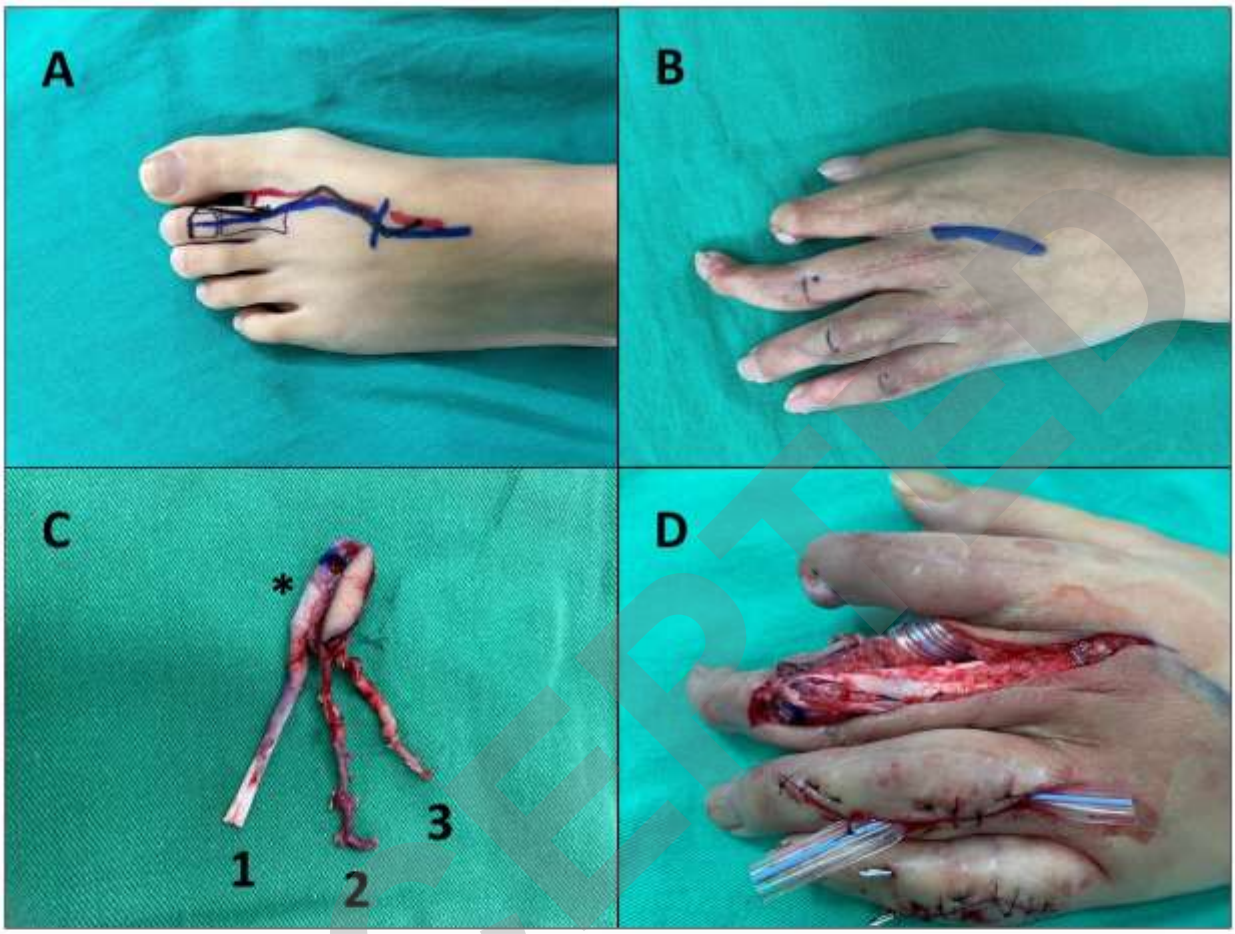




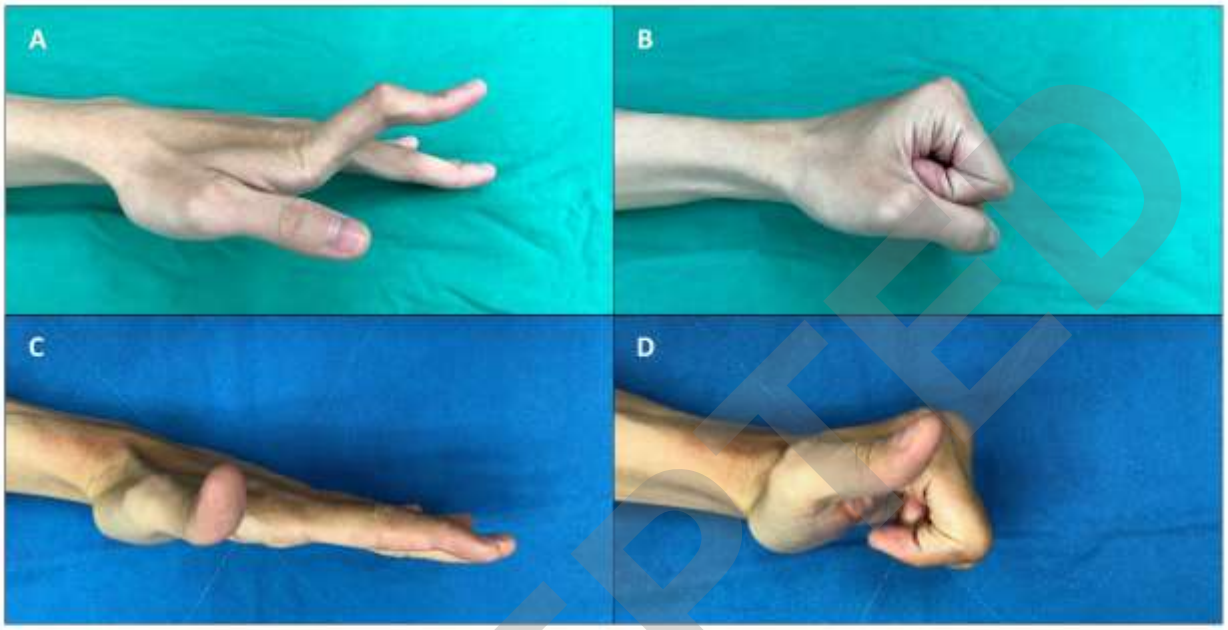
Intraoperative photographs demonstrating the surgical technique step by step.
(**A**) Tenolysis of extensor tendon. (**B**) Release of lateral bands.
(**C**) Marking transection of ulnar slip. (**D**) Transection of ulnar slip.



(**E**) Marking length and stab incision of radial band. (**F**) Stabbing of radial slip.
(**G**) End-to-side tenorraphy. (**H**) Passive and active motion testing.



Pre-, intra- and postoperative photographs demonstrating case #3 which received a combined free vascularized toe transfer and repair of the third digit of the left hand. (**A**) Preoperative markings of the left foot for the harvest of a vascularized toe transfer. (**B**) Preoperative markings of the third, fourth and fifth digit of the left hand. (**C**) Harvested free toe transfer with (*) joint and skin island. Highlighted are **1**. extensor tendon, **2**. vein and **3**. artery. (**D**) Intraoperative results after successful vascularized toe transfer to the third digit, tenolysis of the extensor tendon of the fourth and PIP arthrodesis of the fifth digit.



Photographs of patient case #4 and function of the second digit. (**A**) and (**B**) Preoperative functional assessment displaying severe Boutonnière deformity.
(**C**) and (**D**) Postoperative assessment showing significantly better extension of the PIP joint.