Anatomic Repair of the Central Slip with Anchor Suture Augmentation for Treatment of Established Boutonniere Deformity

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Background: The rupture of the central slip of an extensor tendon of a finger causes a boutonniere (or buttonhole) deformity, characterized by pathologic flexion at the proximal interphalangeal (PIP) joint and hyperextension at the distal interphalangeal (DIP) joint. Currently, there are no standard treatment guidelines for this deformity. This study aimed to report clinical results of surgery to correct chronic boutonniere deformity.

Methods: This retrospective case series was conducted between January 2010 and December 2018 and only 13 patients with trauma-induced chronic deformity were included. After excision of elongated scar tissue, a direct anatomic end-to-end repair using a loop suture technique with supplemental suture anchor augmentation was conducted. Total active motion was assessed before and after surgery and self-satisfaction scores were collected from phone surveys.

Results: All patients presented with Burton stage I deformities defined as supple and passively correctable joints. The initial mean extension lag of the PIP joint (43.5°) was improved by an average of 21.9° at the final follow-up ($p < 0.001$). The mean hyperextension of the DIP joint averaged 19.2° and improved by 0.8° flexion contracture ($p < 0.001$). The average total active motion was 220.4° (range, 160°–260°). Based on the Souter's criteria, 69.2% (9/13) of the patients had good results. Only 1 patient reported fair outcome and 23.1% (3/13) reported poor outcome. The average Strickland formula score was 70 (range, 28.6–97.1). In total, 10 patients (77%) had excellent or good results. Of 10 patients contacted by phone, self-reported satisfaction score was very satisfied in 2, satisfied in 3, average in 3, poor in 1, and very poor in 1. Three patients reported a relapse of the deformity during range of motion exercises, 1 of whom underwent revision surgery. One patient complained of PIP joint flexion limitation, and 2 complained of DIP joint flexion limitation at final follow-up.

Conclusions: In chronic boutonniere deformity, central slip reconstruction with anchor suture augmentation can be an easily applicable surgical option, which offers fair to excellent outcome in 77% of the cases. The risk of residual extension lag and recurrence of deformity should be discussed prior to surgery.

Keywords: *Boutonniere deformity, Proximal interphalangeal joint, Central slip repair, Suture anchor*

Injuries to the central slip portion of the extensor tendon account for 2% of all hand injuries requiring medical attention.[1] The rupture of the central slip of the extensor tendon of a finger causes a boutonniere (or buttonhole) deformity, characterized by flexion pathology at the proximal interphalangeal (PIP) joint and hyperextension at the distal interphalangeal (DIP) joint.[2] When the central slip

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is injured, there is a loss of PIP joint extension function with extension lag, but the distal joint is not disturbed. Later, due to tearing of the transverse ligament and the expansion between the central and lateral slips, the lateral bands become displaced towards the front of the axis of the PIP joint and begin to hyperextend the distal joint.[3]

Boutonniere deformity mostly occurs from traumatic injury but atraumatic attenuation, including rheumatoid arthritis, osteoarthritis, prolonged flexion contracture as seen with Dupuytren's contracture, flexor pulley disruptions, and burns, is also a cause.[4,5] Various treatment methods are currently utilized, including conservative treatment, anatomical reconstruction, tendon grafting, tendon transplantation, central tendon shortening, and lateral band reconstruction. However, there is no standard treatment guideline, and evidence regarding the various treatment outcomes is insufficient.[6,7]

In surgical attempts for chronic boutonniere deformity, some surgeons have focused on the injured central slip, pursuing anatomic restoration of the central tendon in different ways.[6,8,9] Our study focused on chronic boutonniere deformity induced by central slip injury due to close or open trauma. Patients were treated by direct anatomic repair after excision of elongated scar tissue, using a loop suture technique. Furthermore, we supplemented with suture anchor augmentation. The aim of the study was to describe the clinical course of boutonniere deformity before and after treatment and to report clinical results of corrective surgery.

METHODS

This retrospective case series was conducted between January 2010 and December 2018 under the approval of the Institutional Review Board of CHA Bundang Medical Center (IRB No. CHAMC 2020-05-003). Patient consent was waived due to the retrospective study design.

There were 30 patients in the institution's medical records system who underwent surgical treatment after the diagnosis of boutonniere deformity. Patients with chronic boutonniere deformity from central slip injury who were treated with direct repair with anchor suture augmentation were included. Patients with chronic boutonniere deformity who were treated with other methods, those with a disease-induced deformity or deformity other than from central slip trauma, and cases of acute injury less than 6 weeks from trauma were excluded (Fig. 1). Overall, 13 patients were enrolled: 11 male and 2 female patients with a mean age of 34.5 years (range, 13–61 years). All patients presented with Burton classification stage I, featuring

supple and passively correctable boutonniere deformity without osteoarthritic changes.[10] Deformities were present in the right hand in 7 patients and the fifth digit was the most frequently involved finger (8 patients, 61.5%) followed by the third digit (3 patients, 23.1%) and the second digit (2 patients, 15.4%).

The major injury mechanisms were closed rupture in 6 patients (46.2%) and laceration injury in 5 patients (38.5%). The remaining 2 patients (15.4%) presented with boutonniere deformity after foreign body removal and tenosynovectomy due to calcific tenosynovitis in the PIP joint (Table 1). Surgical treatment was decided for the following reasons: failed conservative management (n = 4), failed central tendon repair at another hospital (n = 2), occurrence after other surgical procedures (n = 2), reference from another hospital for operation (n = 2), and patient's desire for operation (n = 3).

The median time to surgery was 38.9 months (range, 6.5 weeks–30 years) after the first diagnosis of boutonniere deformity was confirmed by PIP extension deficit and DIP hyperextension upon physical examination. The extension lag of the PIP joint and hyperextension of the DIP joint in active full extension of the affected finger were measured on lateral plain radiographs. The average follow-up period was 16 months after the corrective operation. The active PIP and DIP joint range of motion (ROM) was measured at an outpatient final clinical follow-up and compared to preoperative measurements as a clinical outcome. Total active motion (TAM) was measured and categorized as excellent (ROM > 240°), good (ROM, 220°–239°), fair (ROM, 180°–219°), and poor (ROM < 180°).[11] Functional evaluation was performed according to Souter's criteria[12] and the Strickland formula.[13]

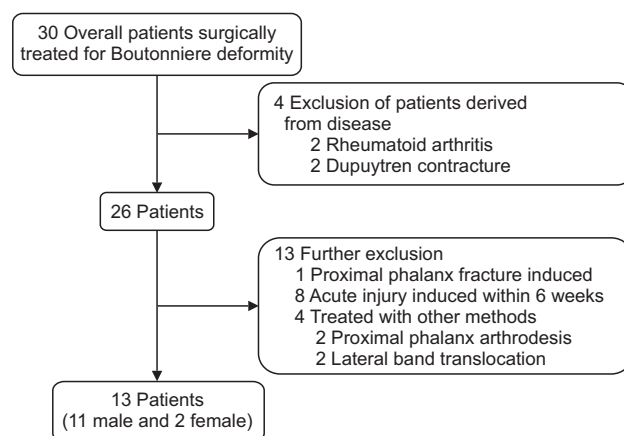Souter's criteria was used to evaluate extension loss

Fig. 1. Flowchart of patient selection.

Table 1. Basic Characteristics of Patients

No.	Sex	Age (yr)	Direction	Digit	Injury mechanism	Physical examination (°)		Lateral plain X-ray (active full extension, °)		Interval (injury to surgery)	Follow-up (mo)
						PIP extension lag	DIP hyperextension	PIP extension lag	DIP hyperextension		
1	M	45	Left	Long	Sickle cut, neglected	60	20	69.2	25.6	30 yr	8
2	M	50	Right	Small	Falling on ground	50	10	70.9	8.0	3.3 mo	34
3	F	14	Right	Small	Hit by volleyball	45	20	28.5	27.7	2 yr	9
4	M	34	Left	Index	Knife cut, only skin suture	20	35	11.8	36.3	7 wk	5
5	M	22	Left	Small	After surgery of foreign body removal	30	30	37.6	31.7	6 mo	7
6	M	13	Left	Small	Falling on ground during soccer	40	10	42.9	5.0	3 mo	38
7	M	27	Right	Small	Punch machine	30	20	29.7	28.6	5 mo	11
8	M	35	Right	Small	Rerupture after central tendon repair	60	10	70.5	12.8	5 yr	12
9	M	21	Right	Small	Hit by basketball	60	20	75.1	12.2	2.5 mo	7
10	M	35	Left	Small	Rerupture after central tendon repair	40	20	47.8	30.1	9.5 mo	18
11	M	59	Left	Long	Sickle cut, neglected	50	25	55.5	37.9	6.5 wk	23
12	F	33	Right	Long	After tenosynovectomy	50	10	62.2	11.7	15 mo	12

PIP: proximal interphalangeal joint, DIP: distal interphalangeal joint.

of the PIP joint: absence of extension loss was rated as perfect, less than 10° of loss as very good, less than 20° as good, less than 40° as fair, and more than 40° as poor. [12] In the case of Strickland score, the active ROM of the PIP joint (PIPJ) and that of DIP joint (DIPJ) are summated (the maximum value being 175°) and expressed as a percentage, as shown in the following formula:

$$\text{Strickland score} = \frac{\text{PIPJ}_{rom} + \text{DIPJ}_{rom}}{175} \times 100$$

Strickland score is graded as follows: excellent (75–100), good (50–74), fair (25–49), and poor (0–24).[13]

As a subjective outcome, patients were contacted by phone during the study period and asked to rate their current satisfaction with the operation with the following possible responses: very satisfied, satisfied, average, poor,
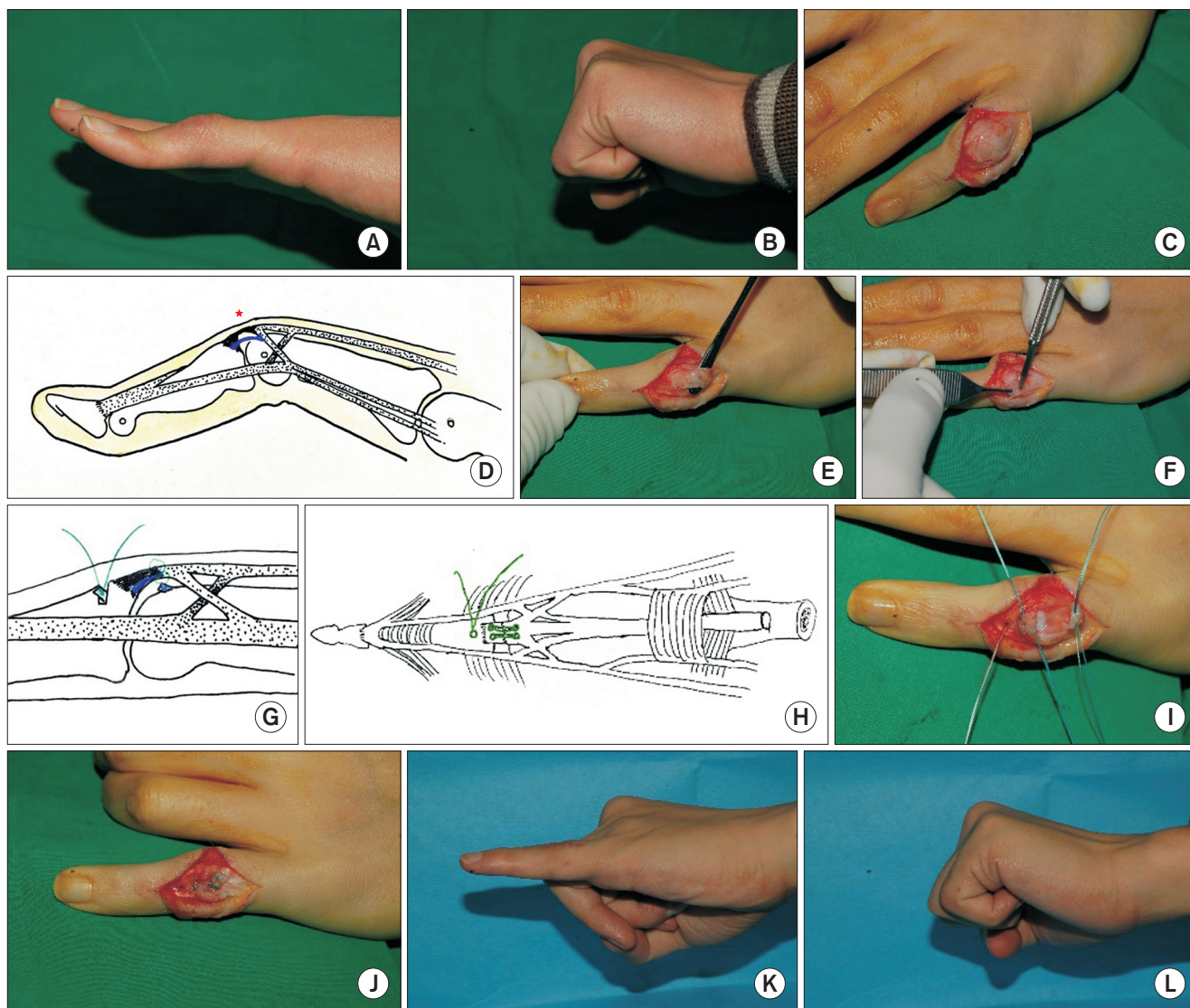

Fig. 2. (A, B) A 22-year-old man with a 30° extensor lag of the proximal interphalangeal (PIP) joint and 30° hyperextension of the distal interphalangeal joint at 3 months after the initial injury. (C, D) With a lazy S-shaped incision over the PIP joint, the elongated scar tissue was identified within the underlying joint capsule (asterisk). (E) The bilateral sides of the central tendon were incised and released for advancement. (F) An appropriate length of scar tissue including the underlying joint capsule was resected for PIP full extension. (G-J) The proximal stump was advanced and the end repair was performed between the proximal and distal stump containing the joint capsule, using four-strand core sutures at 0° PIP extension. An additional Mitek Micro Quick Anchor was inserted and sutured to the proximal stump to enhance suture stability. (K, L) At the final clinical follow-up, the range of motion was recorded.

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and very poor. Postoperative complications were also investigated, including superficial or deep infection, PIP and DIP joint flexion limitation, deformity relapse, occurrence of swan neck deformity, persistent pain after surgery, osteoarthritic changes, and reoperation.[14]

Surgical Technique

Fig. 2A and B shows a fifth left finger that had a 30° extension lag of the PIP joint and 30° hyperextension of the DIP joint that was passively correctable. We approached the PIP joint dorsum with a lazy S-shaped incision and identified loosening of the central slip tendon. Elongated scar tissue was formed over the injured central slip (Fig. 2C and D). A bilateral incision and release between the retracted central slip and the lateral bands of the extensor expansion were conducted (Fig. 2E). An appropriate length of scar tissue for PIP full extension was resected including the underlying joint capsule (Fig. 2F). The proximal central slip segment was repaired into the distal stump containing the joint capsule at the PIP joint tension of 0°. The repair of the central slip tendon was conducted as tight as possible. We performed direct repair of the central slip with No. 3-0 Ethibond Excel Polyester suture (Ethicon Inc., Somerville, NJ, USA) by four-strand core double looped sutures and augmentation using a small joint anchor (Mitek Micro Quick Anchor; DePuy Mitek, Norwood, MA, USA) (Fig 2G-J). The release of the lateral band was left without further management. Depending on the sutured tendon status, we supplemented PIP extension with a transarticular Kirschner wire (K-wire) at 0° extension for temporary holding. After surgery, mobilization of the DIP joint was allowed as tolerated. However, immobilization of the PIP joint was maintained using an aluminum splint for approximately 4 weeks, and gradual joint motion began 4 weeks after surgery. A selective dynamic splint was used as ROM started. At the final clinical follow-up, the ROM was recorded (Fig. 2K and L) .

Statistical Analysis

All variables are summarized as mean, range, and number (percentage, %). The Wilcoxon rank-sum test was used, and paired *t*-tests were performed to compare pre- and postoperative PIP joint extension lag and DIP joint hyperextension. A *p*-value less than 0.05 was considered statistically significant. Statistical evaluation was conducted using R software ver. 3.1.0 (Comprehensive R Archive Network, GNU General Public License).

RESULTS

The surgery was performed under local anesthesia in 4 patients, brachial plexus block in 3 patients, and general anesthesia in 5 patients. The average operative time was 50.4 minutes (range, 35–85 minutes). In 7 cases, the temporary K-wire fixed for holding the PIP joint was removed approximately 4 weeks after surgery when increased ROM was encouraged. An intermittent dynamic splint was used in 4 patients since the patients presented with extension lag as ROM resumed approximately postoperative 4 weeks. The initial mean extension lag of the PIP joint, 43.5° (range, 60°–20°), was improved by 21.9° (range, 0°–70°) at the final follow-up (*p* < 0.001). The mean preoperative ROM of the DIP joint, which was –19.2° (range, –10° to 35°) indicating hyperextension, improved to 0.8° (range, –10° to 15°) extension (*p* < 0.001) (Table 2). The average TAM was 220.4° (range, 160°–260°) with 7 patients (54%) classified as good.

Based on the Souter's criteria, 69.2% (9 out of 13 patients) had good results, 1 patient had a fair outcome, and the rest (3 out of 13 patients, 23.1%) had a poor outcome. The average Strickland formula score was 70 (range, 28.6–97.1). In total, 10 patients (77%) had excellent or good results and the rest had fair outcomes (3 patients, 23%). During follow-up by phone, 10 out of 13 patients were contacted. The satisfaction score was very satisfied in 2, satisfied in 3, average in 3, poor in 1, and very poor in 1. Three patients reported a relapse of boutonniere deformity during ROM exercise with similar preoperative condition. One patient underwent revision surgery with bilateral lateral band dorsal translocation, which was then sutured together. At final follow-up, the patient presented with a flexion contracture of 20° and a further flexion of 90° for the PIP joint, but the DIP joint was almost fixed in 5° of flexion, indicating poor outcome. Two patients refused further management. Another patient complained of PIP joint flexion limitation with only 60° flexion. Two patients complained of DIP joint flexion limitation at the final follow-up.

DISCUSSION

Despite chronic boutonniere deformity, restoration of the central band after scar tissue excision using loop suture and anchor suture augmentation resulted in reduction of the PIP extension lag and DIP hyperextension from 43.5° to 21.9° and from 19.2° to –0.8°, respectively. However, 3 of 13 patients postoperatively presented with a boutonniere deformity similar to the preoperative condition, with

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Table 2. Results

No.	Active range of motion (°) at the final follow-up					Functional score		Satisfaction	Complication
	PIP flexion	PIP extension	DIP flexion	DIP extension	TAM (°/grade)	Souter criteria	Strickland formula	Grade	
1	90	70*	20	−10†	160/Poor	Poor	Fair	Very poor	Deformity relapse, reoperation
2	90	40	20	−5	165/Poor	Poor	Fair	Average	Deformity relapse, DIP flexion limitation
3	85	30	40	5	200/Fair	Fair	Good	Missing	
4	100	0	70	0	250/Excellent	Perfect	Excellent	Satisfied	
5	110	0	65	10	250/Excellent	Perfect	Excellent	Missing	
6	100	0	65	0	260/Excellent	Perfect	Excellent	Satisfied	
7	100	20	65	15	240/Excellent	Good	Excellent	Missing	
8	60	15	65	0	205/Fair	Good	Good	Average	PIP flexion limitation
9	90	70	50	−10	170/Poor	Poor	Fair	Poor	Deformity relapse
10	100	10	60	5	235/Good	Very good	Excellent	Very satisfied	
11	100	10	70	0	260/Excellent	Very good	Excellent	Very satisfied	
12	100	20	65	0	245/Excellent	Good	Excellent	Average	
13	90	0	30	0	210/Fair	Perfect	Good	Satisfied	DIP flexion limitation
Mean	93.5	21.9	52.7	0.8	220.4				

PIP: proximal interphalangeal joint, DIP: distal interphalangeal joint, TAM: total active motion.
*Indicates extension limitation. †Indicates hyperextension.

1 patient undergoing revision surgery. Although boutonniere deformities are easily recognized, the central slip injuries that induce the deformity, especially in chronic cases, are relatively uncommon and the surgeon's experience in treating them may be limited. Thus, surgical indications have not been established due to the lack of a comparison study between conservative and operative treatment.

For patients with chronic, supple, passively corrected boutonniere deformity, conservative management is recommended. Dynamic or serial splinting or casting can be applied for 6 to 12 weeks on the PIP joint in full extension.[15] Souter[12] supported conservative treatment over operative treatment within 6 weeks of injury. Although all patients in the present study presented with Burton classification stage I featuring supple and passively correctable boutonniere deformity, we only included patients with injuries that had been present over 6 weeks from trauma and with 43.5° of PIP extension lag, excluding conservatively treated patients. Moreover, surgical treatment was decided due to failed conservative management (n = 4) and occurrence after acute central tendon repair (n = 2) or other surgical procedures (n = 2). Two patients were referred for

surgical treatment and the remaining 3 preferred operative management over conservative management after sufficient explanation.

In terms of operative treatment, the majority of previous studies that include surgical treatment for boutonniere deformity are retrospective case series and focus on techniques.[7] Furthermore, they used different evaluation methods and surgical methods, which also resulted in different surgical outcomes. Several methods for surgical treatment of boutonniere deformity have been described in the literature including direct repair of the central slip,[12] surgery of the lateral band,[16] terminal tendon tenotomy,[17-20] tendon graft,[21] tendon transfer,[22] and arthrodesis, without evidence indicating a consistently ideal outcome because functional outcome measurements after treatment were also inconsistent.[6,8,12,13]

Dolphin[23] first introduced terminal tendon tenotomy in boutonniere deformity as a simple and effective method to relive DIP extension and improve PIP extension lag. Intentionally creating a mallet finger lessens the extensor tone and facilitates flexion at the DIP joint. Furthermore, the procedure can enhance the PIP extension

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mechanism by proximal sliding of the extensor tendon.[10] Several authors have conducted this simple procedure but outcome measures were limited in previous studies.[19,20] Therefore, the procedure was indicated for mild PIP joint extension lag of less than 30°, which mainly aims for DIP hyperextension correction.[7] Curtis once introduced this procedure as one of phased steps in boutonniere deformity correction.[24]

Lateral band management by mobilization, translocation, and its variations have also been attempted for boutonniere deformity correction.[16,25] With these procedures, several authors have reported considerable PIP extension correction. However, since they do not involve anatomic reconstruction, they present mixed outcomes.[7] More complex methods using tendon grafting or transfer have also been attempted with satisfying outcomes.[21,22] However, due to the complexity, these procedures are less likely to be reproducible with consistent outcomes.

Finally, in the present study, anatomic reconstruction of the injured central slip was performed. There have been several studies describing anatomic restoration of the central slip to manage established boutonniere deformity with modifications of this surgical technique. For example, Pardini et al.[8] treated 25 patients with supple correctable deformities by performing excision of the central slip scar tissue at 1 cm proximal to the middle phalanx base and attempting an end-to-end repair. The lateral bands were then sutured to the central slip and K-wire immobilization of the PIP joint was performed in full extension for 33 days. They found 59% good and 41% poor results with Souter's criteria, which was also used in the present study.[12]

Grundberg[9] used a similar technique: resection of 3 mm of the central slip, end-to-end central slip repair without disturbing the lateral bands, and K-wire fixation at the PIP joint in full extension. Out of 7 patients, 3 patients presented with full PIP joint extension with an average of 90° flexion after 3-mm scar tissue excision. Two patients presented with PIP joint hyperextension of –7° after 7- and 5-mm scar tissue excision. Finally, one patient had 20° PIP extension deficit after 2.5-mm excision. The postoperative PIP joint ROM averaged 7° to 89° and the postoperative DIP joint ROM averaged 7° to 51°.

Caroli et al.[6] reported on the outcome of modified direct anatomical repair of 18 patients with supple and passively correctable late boutonniere deformity. They excised a swallow-tailed flap to enhance the repair contact and performed K-wire fixation in 20 patients with boutonniere deformity. After 4 weeks, the K-wire was removed, and ROM exercise was started. Using their own functional

results assessment, of the 18 patients, 13 had excellent results (72.2%) with near full PIP and DIP joint motion. Fair results in 3 patients (16.6%) were attributed to not following proper postoperative management.

Small-sized suture anchors for use in hand surgery and boutonniere deformity management have been described in the literature.[26-28] Cluett et al.[29] evaluated the pullout strength of the Mitek micro-arc anchor for the reconstruction of central slip avulsions at the PIP joint of the finger. There were no statistically significant differences between the failure loads or the failure mechanisms of the anchor suture group and the horizontal mattress repair group; however, bone anchors offer several advantages over traditional repair techniques as they involve a simple operation with little soft-tissue disruption.

Chan et al.[27] retrospectively evaluated the outcome of 8 digits in 8 patients with central slip injuries, avulsion, or laceration very close to its insertion. The patients underwent central slip repair using only the Mitek micro-quick anchor (DePuy Mitek, Norwood, MA, USA). The PIP joint was then maintained in extension using a two-thirds cylindrical splint and allowed for DIP joint flexion and extension at 2 to 6 weeks. Two patients could perform full extension of the PIP joint, 3 patients showed an extension limitation of 10° or less, and 3 had an extension limitation of 20° or more. By applying additional suture anchor tie in addition to repair of the central tendon, we attempted to reinforce the repair and neutralize tensile force applied on the suture site.

Based on TAM measurement, 53.8% of the patients had excellent or good results. The 69.2% of the patients had good or very good results according to Souter's criteria, and 76.2% of patients had excellent or good results according to the Strickland score. We pursued robust reconstruction by using the PIP dorsal joint capsule as a distal segment flap for repair and a supplementary anchor suture. Finally, temporary fixation of the PIP joint was selectively performed. However, 3 patients presented with deformity relapse equaling the preoperative state. The preoperative PIP joint extension lag was 60° in 2 patients and 50° in 1, which were more severe considering the average of the total patients was 43.5°. Besides, 1 of the patients with a 60° PIP extension lag at the initial visit had trauma 30 years before operation. The patient was retreated with revision surgery involving bilateral lateral band dorsal translocation and suturing. Pardini et al.[8] reported comparatively poor outcomes in cases of more than 2 years after injury. Another patient with deformity relapse took off the immobilization splint at approximately 2 weeks after surgery against the surgeon's protocol. Though we

reapplied the PIP joint extension splint upon finding PIP flexion relapse at 4 weeks, the deformity did not improve. Grundberg[9] recommended 6 weeks of immobilization after anatomic repair of the central tendon out of concern for stretching the central slip, resulting in recurrence of the deformity. However, another concern with this issue is PIP joint flexion limitation.[10,15] In the present study, only 1 patient presented postoperatively with 60° of flexion of the PIP joint. When we contacted with phone, the patient reported improved PIP joint flexion compared to last outpatient follow-up, but still complained of discomfort from a limited fist grip.

Compared with previous outcomes of anatomic central tendon reconstruction, our outcomes were not prominent or outstanding. Kaplan[30] referred to the treatment of established boutonniere deformity as the most difficult secondary repair of the extensor apparatus. Therefore, we believe chronic boutonniere deformity is a challenging issue and surgeons should not guarantee outcomes. Prior to treatment selection, the surgeon should evaluate the degree of deformity, time from injury, and patient concerns and discomfort. If a boutonniere deformity does not affect finger flexion, there is less likely to be pain with rare functional limitations, then the decision of surgical management should be based on sufficient discussion with patients on their requirements and expected outcome. Once the surgical treatment is decided, the present method can produce satisfying outcomes despite the risk of relapse.

There are several limitations to the present study to consider. It is a retrospective case series. The small sample size limits generalizability of the results and there was no control group. Despite many studies in the literature, comparison studies were not available. In the future, the authors hope to conduct a prospective comparison study to inform evidence-based treatment guidelines. Finally, as wide awake local anesthesia no tourniquet (WALANT) surgery has achieved a great deal of improvement in the treatment of tendon injury in the field of hand surgery,[31] the application of the WALANT technique in the surgical treatment of boutonniere deformity is considered to be helpful for future research. In chronic boutonniere deformity, central slip reconstruction with anchor suture augmentation is an easily applicable surgical treatment option producing fair to excellent outcome in 77% of cases. The risk of residual extension lag or recurrence should be discussed prior to surgery.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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