

Stack versus Te Technique for Central Slip Reconstruction during Vascularized Toe Proximal Interphalangeal Joint Transfer

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Background: Significant extension deficit is a common problem after a vascularized toe proximal interphalangeal joint transfer. One of the main causes related to extensor lag is central slip deficiency of the donor toes. In their clinical practice, the authors performed both the Stack and Te techniques to reconstruct central slip function during a joint transfer. The aim of this study was to compare the long-term outcomes of vascularized joint transfers between these two techniques.

Methods: From May of 2009 to October of 2021, 38 digits in 36 patients (28 men and 8 women) underwent free vascularized toe joint transfer requiring central slip reconstruction. Eight and 30 digits were reconstructed with the Stack technique and the Te technique, respectively.

Results: The median length of follow-up was 19 months (range, 5 to 78 months). The overall median extension lag was 20 ± 20 degrees and flexion was 80 ± 20 degrees. There were no significant differences in extension lag (25 ± 29 degrees versus 20 ± 15 degrees; $P = 0.281$), flexion (75 ± 10 degrees versus 85 ± 20 degrees; $p = 0.13$), or range of motion (53 ± 23 degrees versus 63 ± 15 degrees; $P = 0.076$) of the joints between the Stack and Te techniques after the transfers.

Conclusions: From the limited number of cases, both the Stack and Te techniques provided similar outcomes in correcting extension lag in vascularized joint transfers. The Te technique is a simplified and effective method for central slip reconstruction, whereas caution is advised when using the Stack technique because of potential complications. (*Plast. Reconstr. Surg.* 154: 508e, 2024.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.

Reconstructing posttraumatic osteoarthritis of the finger proximal interphalangeal joint (PIPJ) is still a challenge for hand surgeons. The use of a toe vascularized joint transfer (VJT) for finger joint reconstruction was shown to achieve the goal of replacing like-with-like for the autologous reconstruction and functional restoration of the damaged joint. One of the most common observations is significant extension lag of

the transferred toe's PIPJ.^{1,2} Hierner and Berger reported that fair results should be expected because of an average extension deficit of approximately 30 degrees in adults after VJT.³

In our previous studies on donor toe anatomy, we found that the anatomy of toe extensors was partly different from that of the finger, and that there was no obvious central slip insertion into the middle phalangeal base in most of the toes (type I toe, >95%). This may play a major role in the extension lag after VJT with its inherited nature. Therefore, simultaneous central slip reconstruction would be required in most VJTs to correct the extensor deficit because of the native flaw of the toe PIPJ.⁴⁻⁶

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The Stack technique is used to correct a boutonniere deformity.^{7,8} In the earlier practice of the senior author (Y.T.L.), the Stack technique was applied for central slip reconstruction during VJT.⁴ In this procedure, the distally based flexor digitorum superficialis (FDS) tendon is rerouted dorsally through an additional drill tunnel at the middle phalanx of the transferred toe and then woven to the finger extensor at zone IV. Nonetheless, the additional tunneling accompanied by extensive dissection of the periosteum may affect perfusion of the transferred toe joint. The Te technique was developed to avoid the need for extensive periosteum dissection, and it has been used for central slip reconstruction during VJT since 2015.⁹ In our previous reports, both the Stack and Te techniques showed improved outcomes in terms of reducing the extension lag of VJTs; however, the two techniques have not been directly compared in the literature. Therefore, the aim of this study was to compare the outcomes between the Stack and Te techniques for simultaneous central slip reconstruction in VJTs.

PATIENTS AND METHODS

This retrospective study was approved by the institutional review board of Chang Gung Memorial Hospital, and conducted from May of 2009 to October of 2021. We included patients who underwent central slip reconstruction during vascularized toe PIPJ transfers with the Stack or Te technique. We excluded patients who underwent VJTs to the metacarpophalangeal joint and those who needed to undergo tendon grafts for flexor tendon reconstruction or tenolysis. All of the included patients had posttraumatic arthritis after surgical or conservative treatment, with symptoms of finger deformity, PIPJ stiffness, and decreased range of motion. All of the operations were performed by a single senior surgeon (Y.T.L.), and all of the patients followed the same rehabilitation protocol.

Demographic data were obtained from electronic medical records and included age, sex, laterality of the finger, and injured digit. Outcomes were evaluated, including postoperative active range of motion, flexion angle, extension lag, and percentage of use of the transferred joint (postoperative transferred joint range of motion divided by preoperative donor toe joint range of motion). During the follow-up period, the hand therapist used hand goniometry to measure the postoperative outcomes. Secondary revision operations such as tenolysis and corrective osteotomy were also recorded.

In the statistical analysis, the chi-square test or Fisher exact test was used for categorical variables. Because of the limited number of cases in the Stack technique group, the Mann-Whitney *U* test was used for numerical variables. All reported *P* values were two-sided, and a value of $P < 0.05$ was considered significant. All statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY).

Surgical Technique

Skin Paddle Design

The skin paddle of the VJT was designed at the tibial surface of the PIPJ, which exposed the dorsal surface for evaluation and reconstruction of the extensor mechanism and protected the nutrition vessels to the joint. The skin paddle allowed for monitoring of the flap perfusion postoperatively and also facilitated wound closure. Details of flap harvesting are described in our previous study.⁴

Stack Technique. The Stack technique uses native insertion of the FDS as the donor tendon. A 3-mm hole is drilled from dorsal to volar through the middle phalanx of the transferred toe joint. One slip of FDS is then tenotomized randomly at the A1 pulley, and the distally based tendon slip is delivered from volar to dorsal through the 3-mm hole. The tendon slip is then woven to the remaining extensor over the proximal phalanx using the Pulvertaft technique for central slip reconstruction at zone IV^{4,5} (Fig. 1).

Te Technique. In the Te technique, the toe lateral bands are anchored to the middle phalanx of the transferred joint by transosseous suturing. A 4-0 Prolene suture is passed through the parallel drill holes at the toe middle phalanx, which is used for osteosynthesis. The suture is then passed through the periosteum and lateral bands of the toe extensor. The suture is tied at the dorsal surface to create a tendon insertion into the middle phalanx. The periosteum is sutured to cover the exposed wiring and prevent direct contact between the bone and tendon at the proximal phalanx, and the periosteum suture could reinforce the new tendon insertion at the middle phalanx. Finally, tenorrhaphy of the extensor digitorum longus to the central extensor at zone IV is performed following the same method as in the Stack procedure^{9,10} (Fig. 2).

RESULTS

There were 38 digits in 36 patients (28 men and 8 women) whose finger PIPJ was

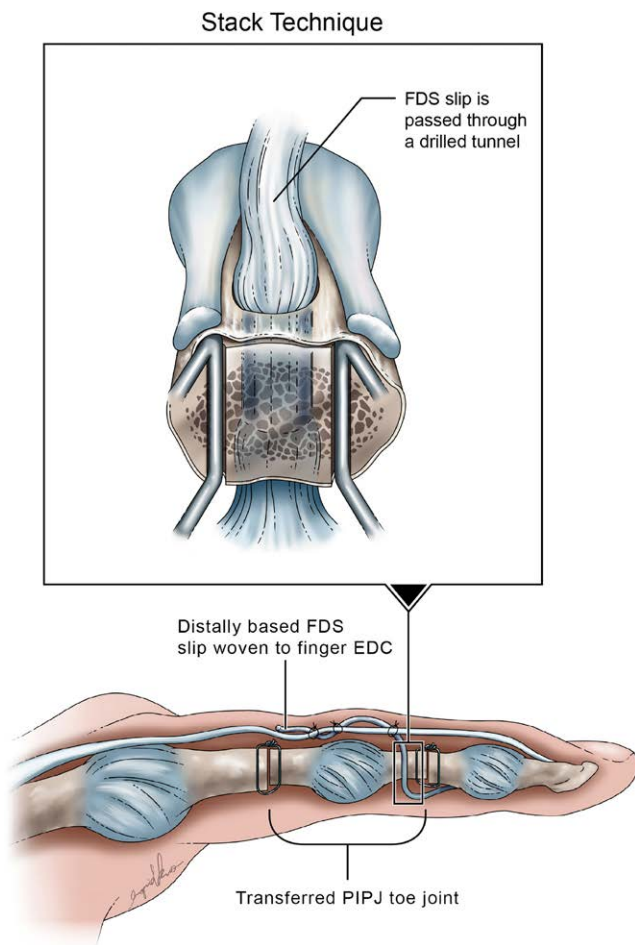


Fig. 1. Illustration demonstrating the Stack technique for recreating the central slip reinsertion. *FDS*, flexor digitorum superficialis; *EDC*, extensor digitorum communis.

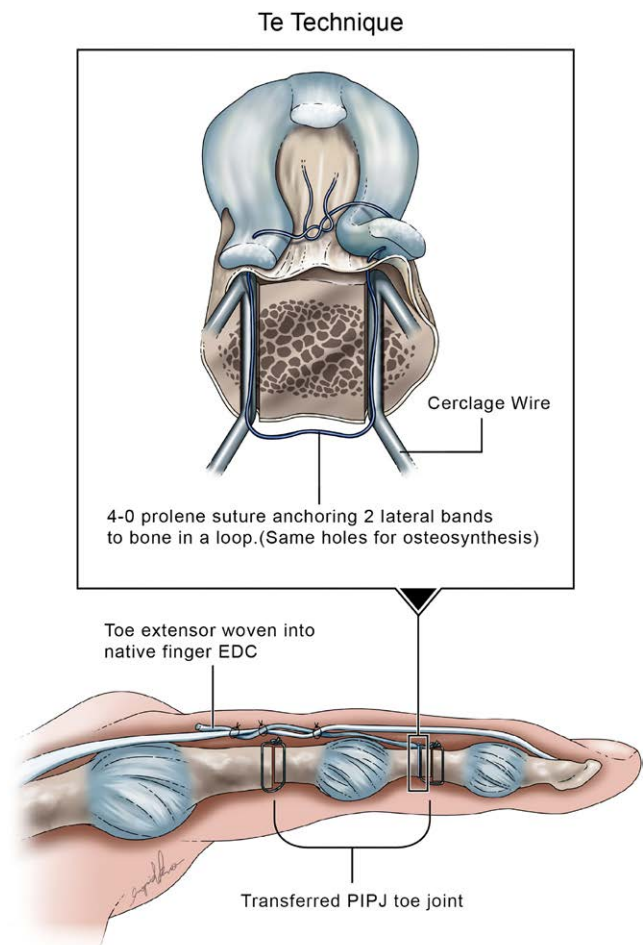


Fig. 2. Illustration demonstrating the Te technique for recreating the central slip reinsertion. *EDC*, extensor digitorum communis.

reconstructed using VJT from the PIPJ of the second toe. The median age was 34 years (range, 5 to 50 years), with 20 right and 18 left fingers. Of the injured digits, 16 index fingers, 14 middle fingers, and 8 little fingers were reconstructed using VJT. Central slip reconstruction was performed in all type I toes with poor lateral bands of the recipient finger, including 8 digits with the Stack technique and 30 digits with the Te technique (Table 1). Two patients underwent 2-digit vascularized joint transfer surgery in the Te technique group. After surgery, the 2 groups received the same postoperative rehabilitation program.

The median duration of follow-up was 19 months (range, 5 to 78 months). All of the joints survived, with no cases of microvascular compromise. The median extension lag was 20 ± 20 degrees (range, 0 to 50 degrees) of the transferred VJT, and the flexion was 80 ± 20 degrees (range, 55 to 95 degrees). The median range of motion was 60

± 20 degrees (range, 20 to 90 degrees), accounting for 80% of the functional use calculated from the original toe PIPJ passive range of motion. In the comparative outcomes analysis, there were no significant differences in reconstructed PIPJ in extension lag (25 ± 29 degrees versus 20 ± 15 degrees; $P = 0.281$), flexion (75 ± 10 degrees versus 85 ± 20 degrees; $P = 0.13$), or range of motion (53 ± 23 degrees versus 63 ± 15 degrees; $P = 0.076$) between the Stack and Te techniques. In addition, there was no significant difference in the percentage of use ($66.7 \pm 55.8\%$ versus $80 \pm 28.5\%$; $P = 0.332$) (Table 2). For the rate of secondary revision after VJT, 2 digits required corrective osteotomy for nonunion or malunion in the Stack technique group compared with 3 digits in the Te technique group (25% versus 10%; $P = 0.279$). Six digits required secondary tenolysis in the Stack technique group compared with 14 digits in the Te technique group (75% versus 46.7%; $P = 0.238$) (Table 3). The native toe range of

Table 1. Patient Demographic between Stack and Te Techniques

Characteristic	Stack (%)	Te (%)	<i>P</i>
No. of digits	8	30 ^a	
Age, yr	33 ± 12	36 ± 13	0.875
Male	7 (88)	22 (73)	0.65
Laterality			
Left side	4 (50)	14 (47)	1.000
Right side	4 (50)	16 (53)	
Injured digit			0.367
Index	2 (25)	14 (47)	
Middle	3 (38)	11 (37)	
Ring	3 (38)	5 (17)	
Follow-up, mo	40 ± 61	18 ± 34	0.265

^aTwo patients underwent 2-digit reconstruction in Te technique group.

Table 2. Evaluation of Finger PIPJ between Stack and Te Techniques

Characteristic	Stack	Te	<i>P</i>
No. of digits	8	30	
Extension lag, deg	25 ± 29	20 ± 15	0.281
Flexion, deg	75 ± 10	85 ± 20	0.13
Range of motion, deg	53 ± 23	63 ± 15	0.076
Percentage of use	66.7 ± 55.8	80 ± 28.5	0.332
Operative time, min	455 ± 130	508 ± 106	0.14

Table 3. Secondary Revision after VJT between Stack and Te Techniques

Characteristic	Stack (%)	Te (%)	<i>P</i>
No. of digits	8	30	
Tenolysis	6 (75)	14 (46.7)	0.238
Corrective osteotomy	2 (25)	3 (10)	0.279

motion was also evaluated before surgery, and no significant differences were found in extension lag (8 ± 13 degrees versus 5 ± 10 degrees; *P* = 0.265), flexion (73 ± 16 degrees versus 80 ± 10 degrees; *P* = 0.112), or range of motion (68 ± 16 degrees versus 75 ± 10 degrees; *P* = 0.096) between the 2 groups (Table 4).

DISCUSSION

Previous systematic reviews have reported that flexion of reconstructed joints can usually achieve a similar degree of flexion of the toe joint before transfer.^{1,11,12} Because of the deficiency of central slip insertion among most toes, extension of the transferred joint may be unsatisfactory if reconstruction of the extensor mechanism is not addressed during VJT. Moreover, the diverse preoperative condition of injured fingers means that no single surgical technique can suffice for every extensor mechanism reconstruction procedure.

Table 4. Evaluation of Donor Second Toe PIPJ between Stack and Te Techniques

Characteristic	Stack (%)	Te (%)	<i>P</i>
No. of digits	8	30	
Extension lag, deg	8 ± 13	5 ± 10	0.265
Flexion, deg	73 ± 16	80 ± 10	0.112
Range of motion, deg	68 ± 16	75 ± 10	0.096

The extensor reconstruction should therefore be customized according to the condition of the recipient fingers and the distinct anatomy of the toes. We suggest that centralization of the lateral band(s) at zone III can be considered when the intrinsic function has been lost. In addition, for those with acceptable intrinsic and extrinsic extensors, central slip reconstruction during VJT is required for toes with an attenuated central slip (type 1 toes). Direct extensor digitorum longus to extensor digitorum communis repair should only be applied to toes with a central slip insertion into the middle phalangeal base (type 2 toes).^{4-6,9}

For central slip reconstruction, we used the Stack technique for VJT in our earlier practice. This procedure seemed to provide acceptable joint mobility in the first few cases. However, the Stack technique required drilling an additional tunnel at the middle phalanx of the short toe joint flap through which the FDS tendon slip was passed from volar to dorsal surfaces. The drilling might jeopardize the perfusion of the transferred joint after extensive dissection of the periosteum. To reduce this risk, the Te technique was developed to allow for central slip reconstruction during the VJT.

In our series, the overall range of motion and the extensor deficit were better compared with a previous systematic review of the VJT.^{11,12} We found that the Te technique exhibited favorable

trends in terms of range of motion and extension lag when compared with the Stack technique, despite the lack of statistical significance in the analysis. In addition, the secondary revision rate for the Te technique appeared to be lower than that for the Stack technique, possibly because of less dissection of the donor and the recipient sites. Nonetheless, the statistical power was relatively limited because of the small number of included patients (power, 0.22). Since 2015, we have been using the Te technique and have chosen to discontinue the use of the Stack technique because of concerns regarding extensive periosteum dissection. As a result, the number of patients in the Stack method group is anticipated to remain limited in the future.

Among the 8 digits reconstructed by the Stack technique, no instances of malunion, delayed union, or nonunion were observed in the middle phalanx. Although the extensiveness of periosteum dissection during the Stack technique was a concern, it may not have compromised perfusion of the middle phalanx to induce complications. Nonetheless, nonunion or malunion did occur at the proximal phalanx in our VJT series. This may have been related to differences in the bone shape of the proximal phalanx between the finger and the transferred toe. Examination of the cross-section of proximal phalanges revealed that the toes had a longer anteroposterior axis, whereas the fingers had a longer transverse axis. In addition, fixation with interosseous wiring was preferred, as it reduced the amount of dissection of the periosteum for plating. These factors could have resulted in unstable bony fixation during the osteosynthesis process.

In this study, there was no significant difference in functional outcomes between the Stack and Te techniques. In central slip reconstruction during VJT, the surgical method may not be the key factor affecting the functional results; rather, the quality of extensor tendon of the recipient finger preoperatively may be the decisive factor. Currently, there is no objective classification system for the severity of soft tissue such as tendon, vessels, intrinsic muscle, or extrinsic muscle. Further studies are required to analyze the impact of extensor tendon quality.

The present study has several limitations. First, this was a retrospective comparative study rather than a prospective randomized trial, and the quality of the extensor mechanism of the recipient fingers could not be controlled. In addition, adhesion of the extensor tendon in those with poor-quality tendons before surgery may

have affected the final results. Second, the relatively small number of patients, especially in the Stack technique group, affected the power of the statistical analysis. Nonetheless, the Te technique for central slip reconstruction provided at least similar results.

CONCLUSIONS

From our limited number of cases, both the Stack and Te techniques provided similar and improved outcomes in terms of correcting extension lag in the VJT. The Te technique can be considered a simplified and effective procedure for central slip reconstruction. Although no cases of nonunion, delayed union, or malunion of the middle phalanx were noted after VJT, the Stack technique should be used with caution.

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DISCLOSURE

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