Predictors of Proximal Interphalangeal Joint Flexion Contracture After Homodigital Island Flap

Akito Nakanishi, MD,* Shohei Omokawa, MD, PhD,† Akio Iida, MD,‡ Daisuke Kaji, MD,* Yasuhito Tanaka, MD, PhD‡

Purpose To identify independent predictors of postoperative proximal interphalangeal (PIP) joint contracture after direct-flow homodigital island flap transfer.

Methods Forty-four fingertip amputations in 39 patients treated with oblique triangular flaps were evaluated at a minimum of 1 year after surgery. Five variables were examined: patient age, injured finger, mechanism of injury, flap advancement distance, and time required for wound healing. Univariate and multivariate linear regression analyses were performed to identify the extent to which these variables affected the flexion contracture of the PIP joint.

Results The average reduction in the passive extension angle of the PIP joint was 16° at final follow-up. Univariate analysis indicated significant correlations of PIP joint flexion contracture with age, injured finger, and time for wound healing, but no significant correlation with the distance the flap was advanced. Multivariate analysis indicated that the age and duration of wound healing were independent predictors of the flexion contracture of the PIP joint.

Conclusions Elderly people and cases with delayed wound healing are at risk for postoperative PIP joint contracture after homodigital flap transfer. Intervention with early hand therapy and orthotics may be useful in elderly patients with delayed wound healing. *(J Hand Surg Am. 2015;40(11):2155–2159.*

Type of study/level of evidence Prognostic II.

Key words Homodigital island flap, advancement flap, flexion contracture, proximal interphalangeal joint, predictor.

HOMODIGITAL ISLAND FLAP TRANSFER is useful in fingertip reconstruction.[1] This flap can also be used as a vascularized bed for the graft-on flap method.[2,3] Advantages of the homodigital island flap include stable and sensate wound coverage and relatively simple flap elevation. Kojima et al[4] and Matsui et al[5] found empirically that the flap can be advanced to a maximum of approximately 15 mm by releasing the neurovascular pedicle proximally to the proximal phalangeal level. Potential disadvantages of the flap include sensory disturbance of the fingertip when the flap is advanced more than 12 mm and a flexion contracture of the proximal interphalangeal (PIP) joint.[6,7] The purpose of this prospective cohort study was to identify the determinants of postoperative PIP joint contracture after direct-flow homodigital island flap transfer with a minimum follow-up of 1 year. A better understanding of risk factors might help with prevention of PIP joint flexion contracture after direct-flow homodigital island flap transfer.

*From the *Department of Orthopaedic Surgery, Takita Hospital; the †Department of Hand Surgery, and the ‡Department of Orthopaedic Surgery, Nara Medical University, Nara, Japan.*

Received for publication February 24, 2015; accepted in revised form August 6, 2015.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

Corresponding author: Shohei Omokawa, MD, Department of Hand Surgery, Nara Medical University, Kashihara Nara, 634-8522, Japan; e-mail: omokawa@gaia.eonet.ne.jp.

0363-5023/15/4011-0005$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2015.08.008

MATERIALS AND METHODS

Between 2006 and 2013, 90 patients with a fingertip amputation at Tamai zone 1 (fingertip to the base of

the nail) or zone 2 (base of the nail to the distal interphalangeal joint) were treated at our institution. Of these patients, 31 underwent digital replantation, composite graft, or revision amputation. The indications for flap surgery were major skin and soft tissue defects of the finger pulp with exposed tendon or bone. Amputations with expected nail growth and regeneration were also good candidates for flap surgery. Twenty patients with a total pulp defect underwent retrograde-flow digital artery flap transfer. A total of 39 patients (44 fingertip amputations) treated with a direct-flow homodigital island flap were enrolled in this study. All 39 patients were informed of the planned treatment and the 1-year follow-up before giving consent (Table 1).

Elevation and advancement of the flap was conducted using the technique originally described by Venkataswami and Subramanian[1] (Fig. 1). The procedure was performed under regional or general anesthesia and 2.5X surgical loupe magnification. A midlateral incision was made from the finger web to the outlined flap. The neurovascular bundle was dissected free of the surrounding tissue in a circumferential fashion from the distal to the proximal incision up to the finger web. This release prevented the pedicle from potential tethering by structures, including Clelands and Graysons ligaments. The flap was inset to cover the fingertip defect and sutured to the surrounding skin using 5-0 chromic suture. In addition to the mobilization gained by complete dissection of the neurovascular bundle, interphalangeal joint flexion of 10° to 20° facilitated advancement of the flap into the defect.

The average length of the flap was 12 mm (range, 7−15 mm). All operations were performed by 1 surgeon in a similar fashion. For 12 fingers, the graft-on flap method was used. In this technique, the nail matrix, perionychium, hyponychium, and bone fragment were harvested from the amputated part as a composite graft. Once the homodigital island flap was advanced to replace the finger pulp, this composite graft was then inset directly on the raw surface of the flap. This allowed for preservation of delicate nail complex structures in cases where most of the nail was amputated. For 32 fingers, only the homodigital island flap was used.

On removal of the bulky dressing 4 days after surgery, we applied a dressing, then monitored wound healing 2 or 3 times each week, and recorded the time required for complete healing of the wound. We began active assisted motion at 2 weeks and passive motion at 4 weeks after surgery. At 1 year and at final follow-up (average, 33 months; range, 12−84 months), we assessed for flexion contracture of the PIP joint. The degree of flexion contracture was defined as the reduction in the passive extension angle at the PIP joint, as measured using a standard goniometer.

TABLE 1. Summary of Patients

Patient characteristics	Age (y)	43 ± 17 (16−71)*
	Sex	Male: 32
		Female: 7
Injury characteristics	Injured digit	Index: 14
		Middle: 18
		Ring: 10
		Little: 2
	Mechanism	Clean-cut: 15
		Crushing: 17
		Avulsed: 12
Surgical characteristics	Flap advancement distance (mm)	12.2 ± 2.7 (7−15)*
	Wound healing period (d)	19 ± 9 (8−41)*
	Surgical Procedure	Simple advancement method: 32
		Graft-on flap method: 12
Follow-up period (mo)		20 ± 15 (12−84)*

*Average ± SD (range).

The study was approved by the hospital institutional review board and informed consent was obtained from all patients.

Statistical analyses

Five independent variables were examined: age, injured finger, mechanism of injury, flap advancement distance, and time for complete wound healing. The dependent variable was the degree of flexion contracture of the PIP joint of the affected digit at final follow-up. These variables were included in univariate and multivariate linear regression analyses to determine factors associated with postoperative PIP joint flexion contracture. A backward stepwise procedure was used to test all predictor variables with $P < .05$ in univariate analysis as candidates in final models. An adjusted R^2 value was obtained to reflect the percentage overall variability for each variable in the multiple linear regression model. A sample size calculation (anticipated effect size, 0.73) was performed with a resulting sample size of 37.

RESULTS

All flaps survived completely, and there were no complications such as infection, cold intolerance, or

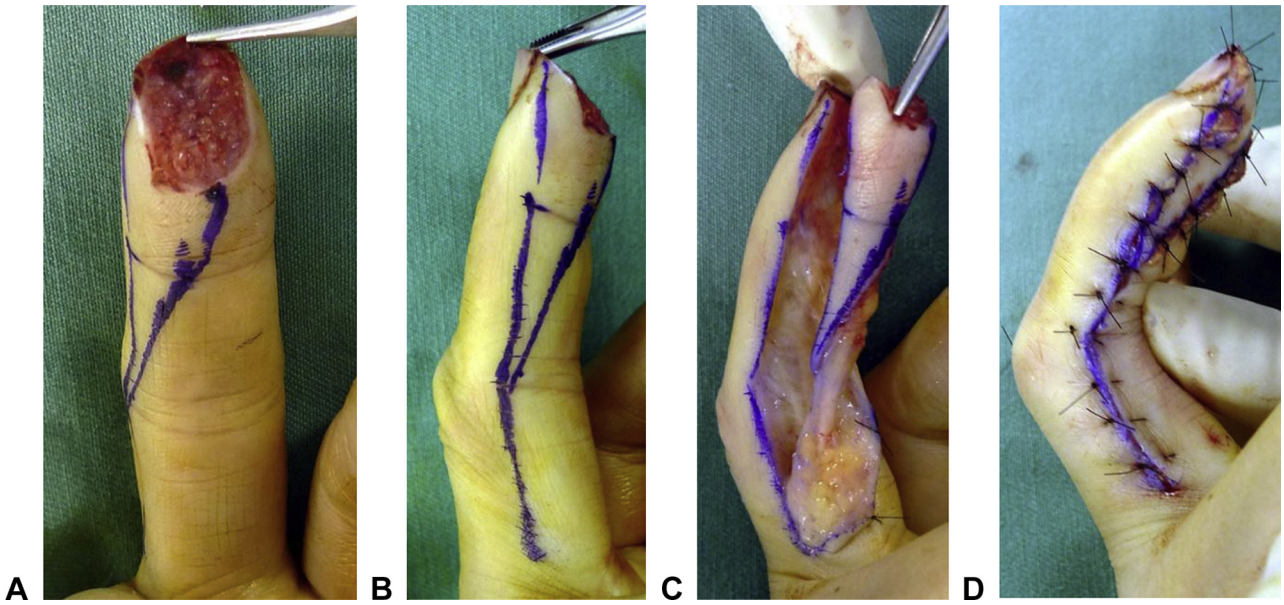

FIGURE 1: A, B Design of an oblique triangular flap. **C** Harvesting of the flap. **D** Advancement of the flap.

TABLE 2. Association of Variables With a Decrease in the PIP Extension Angle

Variables		Decrease in the PIP extension angle	
Age	< 60 y	14° ± 13°	*
	≥ 60 y	24° ± 12°	
Injured digit	Index	9° ± 9°	*
	Middle	17° ± 12°	
	Ring	19° ± 17°	
	Little	35° ± 14°	
Mechanism	Clean-cut	15° ± 14°	
	Crushing	15° ± 16°	
	Avulsed	18° ± 12°	
Flap advancement distance	< 12 mm	15° ± 13°	
	≥ 12 mm	16° ± 15°	
Wound healing period	< 25 d	14° ± 12°	*
	≥ 25 d	28° ± 16°	

*Significant difference in Student's *t* test and 1-way analysis of variance.

chronic regional pain syndrome, as assessed using the Budapest criteria (evaluation of sensory, vasomotor, sudomotor/edema, and motor/trophic properties).[8] No additional surgery was required. The average time for complete wound healing was 19 days (range, 8–41 days) in all cases and 16 and 28 days after simple advancement and a graft-on flap procedure, respectively. All patients were followed for more than 1 year, and the average (± SD) reduction in the passive extension angle of the PIP joint was 16° ± 14° (range, 45° to 0°) at final follow-up.

Univariate analysis indicated that 3 factors were significantly associated with flexion contracture: older age, ulnar digit, and time for wound healing (Table 2). Linear regression analysis showed that a flexion contracture of approximately 20° corresponded to an age of 60 years and a time for wound healing of 25 days. The average loss of extension angle in the index finger was 9° and that in the little finger was 35°. There was no significant correlation between the decrease in extension angle and the advancement distance of the flap or the mechanism of injury. Multivariate analysis including the significant variables in univariate analyses indicated that age and time for wound healing were independent predictors of the flexion contracture of the PIP joint (Table 3). A multiple linear regression model including these 2 factors accounted for 46% of the variability in PIP joint flexion contracture: age, $\beta = 0.51$, $P = .002$; time for wound healing, $\beta = 0.60$, $P = .005$.

DISCUSSION

Several studies have studied the incidence of PIP joint flexion contracture after a direct-flow neurovascular island flap.[7,9,10] Adani et al[7] found a flexion contracture in 8% of patients in a case series and used a dynamic extension orthosis to prevent contracture in several patients. Hand therapy and splinting have

TABLE 3. Multivariate Analysis of Variables Predicting Flexion Contracture (n = 44)

Variables	Partial Regression Coefficient	Standardized Coefficients β	*P* Value	95% CI
(Constant)	−19.65		.005	−6.40 to −32.91
Age	0.43	0.51	.002	0.22 to 0.63
Wound healing period	0.89	0.60	.005	0.51 to 1.28

Adjusted $R^2 = 0.455$; CI, confidence interval.

been used postoperatively in patients with finger stiffness, but a flexion contracture of the PIP joint occurred in 8% to 29% of cases.[9,10]

In the current study, all patients were initially immobilized in 10° to 20° of PIP joint flexion, because of flap inset. Some patients overcame this during the healing process, but others did not. Patient age and time from surgery until complete wound healing were found to be associated with worsening of PIP joint contracture in multivariate linear regression analysis. The final regression model revealed that these two predisposing factors contributed 46% of the total variance in the outcome. These results suggest that elderly patients and delayed wound healing are important risk factors for postoperative PIP joint contracture after direct-flow homodigital island flap transfer.

Patient age was the first significant predictor. Increasing age has been identified in previous studies as a risk factor for the decreased range of finger motion in hand injuries.[11,12] In an investigation of predictors of postoperative finger motion in treatment of comminuted metacarpal and phalangeal fractures, Shimizu et al[13] identified age and associated soft tissue injury as independent prognostic factors. Patients more than 50 years of age are poor candidates for procedures with the thenar flap due to a strong tendency for joint stiffness.[14,15] Preexisting joint arthrosis and muscle weakness in elderly patients may also affect postoperative finger motion. Early hand therapy intervention and an additional extension orthosis at night may be useful in patients older than 60 after homodigital flap transfer.

The time until complete wound healing was the second prognostic factor, with a decreased range of finger motion predicted by delayed wound healing. Wound healing was delayed more in the graft-on flap method than after simple flap advancement. Our analysis did not identify the choice of surgical procedure as a predictor of joint contracture, but delayed wound healing may be caused by factors such as injury mechanism, surgical procedure, and associated injury in the affected hand. Finger swelling secondary to delayed wound healing and a delay in the ability to perform active finger exercises because of prolonged wound dressing may also contribute to decreased finger motion.

Katz[16] showed that advancement of a direct-flow neurovascular island flap was facilitated by flexing the finger. In the current series, approximately 10° to 20° of flexion of the affected finger position was maintained using a dressing and bandage to prevent excessive tension of the vascular bundle.[17] Nevertheless, we found no significant correlation between PIP joint extension loss and flap advancement distance. This result indicates that the distance of flap advancement was not a risk factor for postoperative PIP joint contracture when this distance was less than 15 mm.

There are several limitations of this study. First, we evaluated flexion contracture after a single procedure with an oblique triangular flap, but there are several modifications of the homodigital flap advancement method that may cause different degrees of postoperative flexion contracture of the PIP joint. Second, predictors such as time from injury to surgery or associated injuries may also contribute to flexion contracture, and a greater sample size is needed to investigate these possible predictors. Finally, we evaluated the postoperative joint contracture as a dependent variable. Because finger joint contracture may impair fine motor skills, analysis of finger dexterity would be important in assessment of activities of daily living in patients with flap surgery. Thus, further studies are needed to evaluate manual dexterity as a dependent variable. Within these limitations, the current analysis provides additional information on predisposing factors for finger stiffness after finger flap surgery. Prolonged wound healing in elderly patients may be a significant risk factor and should be included in the preoperative informed consent.

REFERENCES

1. Venkataswami R, Subramanian N. Oblique triangular flap: a new method of repair for oblique amputations of the fingertip and thumb. *Plast Reconstr Surg*. 1980;66(2):296–300.

2. Hirase Y, Kojima T, Fukumoto K, Yamaguchi T. A new treatment procedure for fingers amputated at the nail bed level. *J Jpn Soc Surg Hand*. 2003;20(5):501–504 [in Japanese with English abstract].
3. Netscher DT, Meade RA. Reconstruction of fingertip amputations with full-thickness perionychial grafts from the retained part and local flaps. *Plast Reconstr Surg*. 1999;104(6):1705–1712.
4. Kojima T, Uchida N, Sakurai N, Tsuchida Y, Kudo A. Neurovascular pedicle island flap for the amputated stump of the finger. *Jpn J Trauma Occup Med*. 1988;36(11):824–831 [in Japanese with English abstract].
5. Matsui M, Wakamatsu S, Maeda H, Sakakida S, Oki R. Combining innervated finger flap with composite nail graft for immediate fingertip replantation. *J Jpn Soc Surg Hand*. 1995;12(4):597–600 [in Japanese with English abstract].
6. Sano K, Ozeki S, Kimura K, Hyakusoku H. Relationship between sensory recovery and advancement distance of oblique triangular flap for fingertip reconstruction. *J Hand Surg Am*. 2008;33(7):1088–1092.
7. Adani R, Busa R, Castagnetti C, Bathia A, Caroli A. Homodigital neurovascular island flaps with direct flow vascularization. *Ann Plast Surg*. 1997;38(1):36–40.
8. Harden RN, Bruehl S, Stanton-Hicks M, Wilson PR. Proposed new diagnostic criteria for complex regional syndrome. *Pain Med*. 2007;8(4):326–331.
9. Braga-Silva J, Gehlen D, Bervian F, da Cunha GL, Padoin AV. Randomized prospective study comparing reverse and direct flow island flaps in digital pulp reconstruction of the fingers. *Plast Reconstr Surg*. 2009;124(6):2012–2018.
10. Kayalar M, Bal E, Toros T, Sugun ST, Ozaksar K, Gurbuz Y. The outcome of direct-flow neurovascular island flaps in pulp defects. *Acta Orthop Traumatol Turc*. 2011;45(3):175–184.
11. Bannasch H, Heermann AK, Iblher N, Momeni A, Schulte-Montig J, Stark GB. Ten years stable internal fixation of metacarpal and phalangeal hand fracture-risk factor and outcome analysis show no increase of complications in the treatment of open compared with closed fractures. *J Trauma*. 2010;68(3):624–628.
12. Omokawa S, Fujitani R, Dohi Y, Tanaka Y, Yajima H. Prospective outcomes of comminuted periarticular metacarpal and phalangeal fractures treated using a titanium plate system. *J Hand Surg Am*. 2008;33(6):857–863.
13. Shimizu T, Omokawa S, Akahane M, et al. Predictors of the post-operative of finger motion for comminuted periarticular metacarpal and phalangeal fractures treated with a titanium plate. *Injury*. 2012;43(6):940–945.
14. Melone CP Jr, Beasley RW, Carstens JH Jr. The thenar flap—an analysis of its use in 150 cases. *J Hand Surg Am*. 1982;7(3):291–297.
15. Smith RJ, Albin R. Thenar "H-flap" for fingertip injuries. *J Trauma*. 1976;16(10):778–781.
16. Katz RD. The anterograde homodigital neurovascular island flap. *J Hand Surg Am*. 2013;38(6):1226–1233.
17. Borman H, Maral T, Tancer M. Fingertip reconstruction using two variations of direct-flow homodigital neurovascular island flaps. *Ann Plast Surg*. 2000;45(1):24–30.