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Hand

Success Rates of Finger Revascularization and Replantation

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Background: Revascularization surgery has been reported to have a higher success rate than replantation due to sufficient venous return. However, in complex cases, success depends on a wide range of indications. This study aimed to investigate success rates in cohorts that included severe cases.

Methods: This single-center, noninterventional, retrospective cohort study included 292 patients (349 digits) who underwent revascularization or replantation at our institution between January 2000 and December 2022. Sex, age, smoking history, comorbidities, affected digit, amputation level, complete or incomplete amputation, type of fracture and mechanism, artery diameter, needle, vein anastomosis in the revascularization subgroup, vein grafting, warm ischemic time, and outcomes were investigated and compared between the revascularization and replantation subgroups of the distal and proximal amputation groups.

Results: In the distal amputation group, the arterial diameter in the revascularization subgroup was larger than that in the replantation subgroup ($P < 0.05$). In the proximal amputation group, the revascularization subgroup had a lower frequency of multiple amputations than the replantation subgroup ($P < 0.05$). Vein grafts were more frequently used in both revascularization subgroups than in the replantation subgroups ($P < 0.05$). However, the other injury severity indices were similar, and the success rates were not significantly different between the subgroups.

Conclusions: The revascularization success rate was similar to that of replantation. Vein anastomosis or vein grafting to the veins should be advocated for revascularization in severe cases where skin bridges may not have sufficient venous return. *(Plast Reconstr Surg Glob Open 2024; 12:e5638; doi: 10.1097/GOX.0000000000005638; Published online 4 March 2024.)*

INTRODUCTION

Various predictive risk factors that affect the survival rate after digital revascularization/replantation have been reported. The success rate of revascularization/replantation varies between studies and depends on the surgeon's technique and the wide-ranging indications under complex cases.[1–6] Revascularization surgery has been reported to have a success rate similar to or greater than that of replantation owing to venous return.[7–11] However, venous return in revascularization may not always be intact in severe cases; previous reports did not always include difficult cases.[1–11] Therefore, the superior success rate of revascularization may be attributed to bias in avoiding complex cases.

Previous reports regarding revascularization/replantation solely focused on the revascularization/replantation of the fingertips or did not consider different aspects between the amputation of fingertips and proximal fingers.[1–11]

Therefore, this study attempted to perform surgery if the artery could be identified, regardless of the possibility of success. The cohort was divided into distal and proximal amputation groups to investigate each group separately. This study aimed to examine the success rates and predictive risk factors for revascularization and replantation in groups that included severe cases in each group.

METHODS

This single-center, noninterventional, retrospective cohort study was conducted in a general hospital between

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January 2000 and December 2022. It included 292 patients (349 digits) who visited our emergency room and underwent revascularization or replantation. Patients with a warm ischemia time more than 24 hours were excluded[12] (Fig. 1). Institutional review board approval was obtained, and each patient provided informed consent.

Data on all patients were amassed from operative reports, inpatient stays, and outpatient visits. The collected data encompassed variables such as sex, age, comorbidities, active smoking, affected side and digit, aspect of amputation (Tamai zone, complete or incomplete and single or multiple),[13] fracture type (none or simple/comminuted) and mechanism (guillotine, avulsion, or crush), artery diameter (a smaller diameter was used in cases of a discrepancies), vein anastomosis in the revascularization subgroup, vein grafting (to arteries or veins), warm ischemic time, and result (survival/failure). We determined the indices of severe cases using the following criteria: ratio of multiple amputation, comminuted fracture, avulsion or crushed amputation, artery diameter, vein graft usage, and warm ischemic time.

Patients who stopped smoking more than 1 month preoperatively were not defined as active smokers. Comorbidities included diabetes mellitus, autoimmune diseases, and vascular disorders such as cerebral infarction, myocardial infarction, and arterial sclerotic occlusion. The zone was determined based on the level of arterial anastomosis or distal arterial anastomosis when using a vein graft. Incomplete amputation was defined as amputation with a skin bridge of greater than 5 mm without arterial circulation.[14]

A comminuted fracture was defined as a fracture that included the edge and diaphyseal comminution. The mechanisms of injury were classified as guillotine, avulsion, or crush amputation. Avulsion amputation was defined as amputation mechanically avulsed by a machine such as a belt conveyor, noodle machines, rollers, or electric drills. Crush amputation was defined as amputation with comminuted fracture or segmental soft tissue damage, excluding mutilated fingers or multiple-level amputation.

The artery diameter was measured using a background sheet with a printed scale (Supermicrosheet;

Takeaways

Question: Revascularization surgery reportedly has a higher success rate than replantation owing to the presence of sufficient venous return. However, is the success rate determined by a wide range of indications?

Findings: In both the distal and proximal amputation groups, the severity of the injury and success rates remained similar between the incomplete and complete amputation subgroups.

Meaning: Vein anastomosis or vein grafting to the veins should be advocated for revascularization in severe cases where skin bridges may not have sufficient venous return.

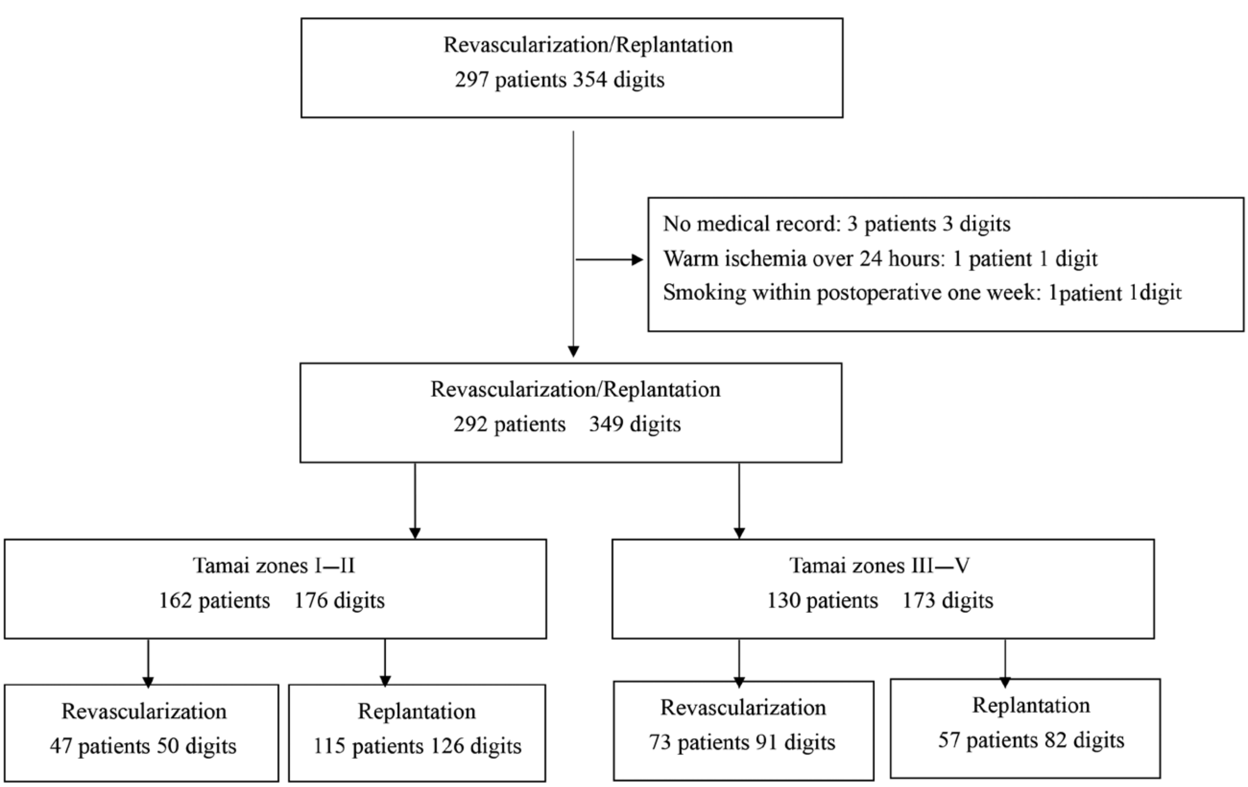

Fig. 1. Flowchart of the study participation. Amputations were divided into Tamai zones I and II (distal amputation group) and Tamai zones III, IV, and V (proximal amputation groups). The groups were further divided into revascularization and replantation subgroups.

Crownjun, Tokyo, Japan) under a microscope at a high magnification (MM50, MM51/YOH: Mitaka Kohki, Tokyo, Japan). The outer diameter of the artery on the sheet was recorded on video before dilatation at a magnification of 50×. The researchers reviewed the video and measured the diameter of the monitor before dilatation. The diameter was determined by consensus. Atrophic fingers were defined as surviving, whereas fingers with an unexpected return to the operating room were categorized as the failure group, regardless of the final result.

The type of anesthesia was general or axillary nerve block. The tourniquet was set at an additional blood pressure of 80 mm Hg (minimum, 200 mm Hg). In the case of axillary nerve block, 20 mL of 7.5 mg ropivacaine was administered for anesthesia.

Six skilled surgeons performed the procedures, and all could anastomose a practice silicon tube of 0.3 mm in diameter using a 12-0 needle within 20 min. The surgery was performed in the following order: bone fixation, tendon suturing, nerve suturing, arterial anastomosis, and venous anastomosis. Reconstructive surgery, such as revascularization and replantation, was indicated based on the patient's preferences. We attempted to anastomose the arteries in the cases of finger revascularization/replantation, even though the diameter was less than 0.5 mm. Furthermore, even in severe cases, we attempted to perform surgery if we could identify the artery, regardless of the possibility of success or function. We anastomosed veins in revascularization in case the surgeon determined that the circulation of the skin bridge was insufficient. The vein graft was harvested from the distal volar forearm or the palmar side of the thenar eminence. The application of the interpositional vein graft was decided by each surgeon depending on the situation.

Upon the completion of digital vessel anastomosis, 2000 units of unfractionated heparin was administered intravenously, followed by 10,000 units of unfractionated heparin daily for 1 week and prostaglandin E1 (20 μg) for 3 days intravenously. Patients were on complete bed rest for 1 week. There were no marked changes in surgical procedures or postoperative protocols between 2000 and 2022.

The cohort was divided into distal (Tamai zones I and II) and proximal (Tamai zones III, IV, and V) amputation groups. We first evaluated differences in variables between the distal and proximal amputation groups to determine the variables that might have caused selection bias in avoiding challenging cases. Subsequently, we compared the variables between the incomplete and complete amputation subgroups. In addition, we compared the variables indicating severity, such as multiple-digit amputation, comminuted fracture, avulsion or crush, and success rate between the revascularization subgroups with and without vein anastomosis.

Categorical variables were evaluated using frequencies and compared using Fisher exact test. Continuous parameters were expressed as medians and interquartile ranges and compared using the Mann–Whitney *U* test. Univariate analysis of each variable was conducted before including the variables in the multivariable logistic regression analysis. We calculated the area under the receiver operating characteristic curve to investigate the model's fitting behavior of the model. A *P* value less than 0.05 was considered statistically significant for all variables. Results are presented as odds ratios (OR) with 95% confidence intervals (CIs). All statistical analyses were performed using the EZR software (Saitama Medical Center, Jichi Medical University, Saitama, Japan).[15]

RESULTS

Tables 1 and 2 present the results of the univariate and multivariable analysis between the distal (Tamai zones I and II) and proximal (Tamai zone III, IV, and V) amputation groups.

Table 1. Univariate Associations between Revascularizations/Replantations of Distal and Proximal Fingers

Variable	Tamai Zones I–II	Tamai Zones III, IV, and V	Results of Univariate Analysis	
	Patients = 162 Digits = 176	Patients = 130 Digits = 173	*P*	95% CI
Sex, male/female (%)	140 (86.4)/22 (13.6)	121 (93.1)/9 (6.9)	*P* = 0.09	0.18–1.12
Age, year [median (IQR)]	49.0 (32.3–58.8)	50.5 (35.8–64.0)	*P* = 0.14	
Comorbidity (yes/no) (%)	12 (7.4)/150 (92.6)	12 (9.2)/118 (90.8)	*P* = 0.67	0.31–1.99
Active smoking (yes/no) (%)	63 (38.9)/99 (61.1)	55 (42.3)/75 (57.7)	*P* = 0.34	0.48–1.30
Side (right/left) (%)	75 (46.3)/87 (53.7)	58 (44.6)/72 (55.4)	*P* = 0.80	0.55–1.56
Digit (T/I/M/R/L) (%)	33 (18.8)/41 (23.3)/50 (28.3)/29 (16.5)/23 (13.1)	19 (11.0)/52 (30.0)/49 (28.3)/34 (19.7)/19 (11.0)	*P* = 0.21	
Complete/incomplete (%)	126 (71.6)/50 (28.4)	82 (47.4)/91 (52.6)	*P* < 0.01	0.22–0.57
Single/multiple (%)	148 (84.1)/28 (15.9)	102 (59.0)/71 (41.0)	*P* < 0.01	2.16–6.34
Fracture (none or simple/comminuted) (%)	166 (94.3)/10 (5.7)	140 (80.9)/33 (19.1)	*P* < 0.01	1.80–9.19
Mechanism (guillotine/avulsion or crush) (%)	141 (80.1)/35 (19.9)	87 (50.3)/86 (49.7)	*P* < 0.01	2.42–6.61
Diameter of the artery (mm) [median (IQR)]	0.6 (0.4–0.8)	1.0 (0.7–1.0)	*P* < 0.01	
Vein anastomosis for incomplete amputation (yes/no) (%)	5 (10.0)/45 (95.0)	15 (16.5)/ 76 (83.5)	*P* < 0.01	0.15–1.78
Vein graft (yes/no)	26 (14.8)/150 (85.2)	59 (34.1)/114 (65.9)	*P* < 0.01	0.19–0.58
Warm ischemic time [median (IQR)]	436.5 (360.0–534.3)	490.0 (410.0–606.0)	*P* < 0.01	
Success/failure (%)	150 (85.2)/26 (14.8)	133 (76.9)/40 (23.1)	*P* = 0.06	0.97–3.13

IQR, interquartile range; T, thumb; I, index finger; M, middle finger; R, ring finger; L, little finger; complete, complete amputation; incomplete, incomplete amputation; single, single-digit amputation; multiple, multiple-digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

Table 2. Multivariable Associations between Revascularizations/Replantations of Distal and Proximal Fingers

Variable	Results of Multivariable Analysis		Results of ROC Analysis				
	P	OR (95% CI)	AUC	95% CI	Cutoff Value	Sensitivity	Specificity
Side (right/left)	$P = 0.70$	0.91 (0.57–1.46)					
Complete/incomplete	$P < 0.01$	0.31 (0.19–0.50)					
Single/multiple	$P < 0.01$	2.82 (1.40–5.70)					
Fracture (none or simple/comminuted)	$P < 0.01$	3.30 (1.49–7.30)					
Mechanism (guillotine/avulsion or crush)	$P < 0.01$	2.40 (1.40–4.13)					
Diameter of the artery	$P < 0.01$	325.00 (79.00–1340.00)	0.83	0.79–0.87	0.90	0.63	0.88
Vein graft (yes/no)	$P < 0.01$	0.43 (0.20–0.90)					
Warm ischemic time	$P < 0.01$	1.00 (1.00–1.00)	0.63	0.57–0.70	447.00	0.66	0.56
Success/failure	$P = 0.09$	1.70 (0.92–3.14)					

ROC, receiver operating characteristic; AUC, area under the curve; T, thumb; I, index finger; M, middle finger; R, ring finger; L, little finger; complete, complete amputation; incomplete, incomplete amputation; single, single-digit amputation; multiple, multiple-digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

Table 3. Univariate Associations between Revascularization and Replantation Subgroups of Distal Fingers

Variable	Revascularization Subgroup	Replantation Subgroup	Results of Univariate Analysis	
	Patients = 47 Digits = 50	Patients = 115 Digits = 126	*P*	95% CI
Sex (male/female) (%)	41 (87.2)/6 (12.8)	99 (86.1)/16 (13.9)	$P = 1$	0.38–3.69
Age, y [median (IQR)]	49.0 (32.0–59.5)	47.0 (33.0–58.0)	$P = 0.98$	
Comorbidity (yes/no) (%)	2 (4.3)/45 (95.7)	10 (8.7)/105 (91.3)	$P = 0.51$	0.05–2.33
Active smoking (yes/no) (%)	21 (44.7)/26 (55.3)	42 (36.5)/73 (63.5)	$P = 0.38$	0.66–2.95
Side (right/left) (%)	24 (51.1)/23 (48.9)	73 (63.5)/42 (36.5)	$P = 0.16$	0.26–1.27
Digit (T/I/M/R/L) (%)	12 (24)/10 (20)/12 (24)/8 (16)/8 (16)	21 (16.7)/31 (24.6)/38 (30.1)/21 (16.7)/15 (11.9)	$P = 0.68$	
Single/multiple (%)	42 (84)/8 (16)	106 (84.1)/20 (15.9)	$P = 1$	0.38–2.81
Fracture (none or simple/comminuted) (%)	46 (92)/4 (8)	120 (95.2)/6 (4.8)	$P = 0.47$	0.13–2.91
Mechanism (guillotine/avulsion or crush) (%)	43 (86)/7 (14)	98 (77.8)/28 (22.2)	$P = 0.3$	0.68–5.12
Diameter of the artery (mm) [median (IQR)]	0.7 (0.5–0.8)	0.6 (0.4–0.7)	$P < 0.05$	
Vein graft (yes/no)	12 (24.0)/38 (76.0)	14 (11.1)/112(88.9)	$P < 0.05$	0.16–1.03
Warm ischemic time [median (IQR)]	419 (346–499.5)	442 (375–545.3)	$P = 0.13$	
Success/failure (%)	44 (88)/6 (12)	106 (84.1)/20 (15.9)	$P = 0.64$	0.49–4.49

IQR, interquartile range; T, thumb; I, index finger; M, middle finger; R, ring finger; L, little finger; complete, complete amputation; incomplete, incomplete amputation; single, single-digit amputation; multiple, multiple digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

Univariate analysis showed that complete, single-digit, and guillotine amputations were more in the distal amputation group than in the proximal amputation group ($P < 0.05$). Moreover, the diameter of the arterial end was smaller ($P < 0.05$).

In contrast, in the proximal amputation group, incomplete and multiple-digit amputations were more ($P < 0.05$). Moreover, there were more comminuted fractures and avulsion/crush amputations, more vein grafts, and longer warm ischemic time ($P < 0.05$). Vein grafting was performed on the digital arteries except for one vein grafting for veins in the proximal replantation subgroup (Table 1).

In multivariable logistic regression analysis, to adjust each variable, we selected "sex," "age," "comorbidity," and "active smoking" as explanatory variables, which showed no statistically significant difference in univariate analysis and possibly affected the survival rate. Variables that showed statistically significant differences in univariate analysis were adjusted by the explanatory variables; however, they still showed statistically significant differences in the multivariable analysis (Table 2).

Table 3 shows the differences between the revascularization and replantation subgroups of the distal amputation group. Univariate analyses revealed that there were more vein grafts, and arterial diameters were larger in the revascularization subgroup than in the replantation subgroup [0.7 (0.1) mm and 0.6 (0.2) mm, respectively; $P < 0.05$]. We found no statistically significant differences except for these variables. No variables showed statistical differences between the distal revascularization subgroup with and without vein anastomosis (Table 4). There were no cases of vein grafting to the veins in the distal amputation group.

In multivariable logistic regression analyses, to adjust each variable, we selected "single or multiple digit amputation," "fracture," and "mechanism" as explanatory variables. Variables that showed statistically significant differences in the univariate analysis still showed statistically significant differences in the multivariable analysis (Table 5).

Table 6 shows the differences between the revascularization and replantation subgroups of the proximal

Table 4. Univariate Associations between Distal Incomplete Amputation with and without Vein Anastomosis

Variable	No Vein Anastomosis	Vein Anastomosis	Results of Univariate Analysis	
	Digit = 45	Digit = 5	*P*	95% CI
Single/multiple (%)	38 (84.4)/7 (15.6)	4 (80.0)/1 (20.0)	*P* = 1	0.06–41.41
Fracture (none or simple/comminuted) (%)	42 (93.3)/3 (6.7)	5 (100.0)/0 (0.0)	*P* = 1	0.00–24.83
Mechanism (guillotine/avulsion or crush) (%)	40 (88.9)/5 (11.1)	4 (80.0)/1 (20.0)	*P* = 0.49	0.04–26.36
Success/failure (%)	41 (91.1)/4 (8.9)	4 (80.0)/1 (20.0)	*P* = 0.42	0.04–36.12

single, single digit amputation; multiple, multiple digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

Table 5. Multivariable Associations between Revascularization and Replantation Subgroups of Distal Fingers

Variable	Results of Multivariable Analysis		Results of ROC Analysis				
	P	OR (95% CI)	AUC	95% CI	Cutoff Value	Sensitivity	Specificity
Sex (male/female)	*P* = 0.90	1.07 (0.39–2.94)					
Age, year	*P* = 0.82	1.00 (0.98–1.02)	0.56	0.47–0.66	47.00	0.55	0.50
Comorbidity (yes/no)	*P* = 0.39	2.00 (0.41–9.81)					
Active smoking (yes/no)	*P* = 0.25	0.66 (0.31–1.35)					
Side (right/left)	*P* = 0.16	0.26–1.27					
Diameter of the artery	*P* < 0.05	0.19 (0.04–0.93)	0.64	0.55–0.73	0.40	0.82	0.33
Vein graft (yes/no)	*P* < 0.05	0.34 (0.14–0.86)					
Warm ischemic time	*P* = 0.16	0.00 (0.00–1.39)	0.63	0.54–0.72	538.00	0.86	0.29
Success/failure (%)	*P* = 0.63	1.28 (0.47–3.51)					

ROC, receiver operatorating characteristic; AUC, area under the curve; T, thumb; I, index finger; M, middle finger; R, ring finger; L, little finger; complete, complete amputation; incomplete, incomplete amputation; single, single-digit amputation; multiple, multiple digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

Table 6. Univariate Associations between Revascularization and Replantation Subgroups of Proximal Fingers

Variable	Revascularization Subgroup	Replantation Subgroup	Results of Univariate Analysis	
	Patients = 73 Digits = 91	Patients = 57 Digits = 82	*P*	95% CI
Sex (male/female) (%)	65 (89.0)/8 (11.0)	56 (98.2)/1 (0.8)	*P* = 0.77	0.00–1.15
Age, y [mean (SD)] [median (IQR)]	48 (39–64)	52 (32–63)	*P* = 0.99	
Comorbidity (yes/no) (%)	9 (12.3)/64 (87.7)	3 (5.2)/54 (94.8)	*P* = 0.23	0.59–15.16
Active smoking (yes/no) (%)	31 (42.4)/42 (57.6)	24 (42.1)/33 (57.9)	*P* = 1	0.46–2.10
Side (right/left) (%)	29 (39.7)/44 (60.3)	29 (50.9)/28 (49.1)	*P* = 0.22	0.30–1.39
Digit (T/I/M/R/L) (%)	12 (13.2)/29 (31.8)/24 (26.4)/18 (19.8)/8 (8.8)	7 (8.5)/23 (28.0)/25 (30.6)/16 (19.5)/11 (13.4)	*P* = 0.72	
Single/multiple (%)	61 (67.0)/30 (33.0)	41 (50.0)/41 (50.0)	*P* < 0.05	1.05–3.94
Fracture (none or simple/comminuted) (%)	71 (79.0)/20 (22.0)	69 (84.1)/13 (15.9)	*P* = 0.39	0.28–1.54
Mechanism (guillotine/avulsion or crush) (%)	52 (57.1)/39 (42.9)	54 (65.9)/28 (34.1)	*P* = 0.28	0.36–1.34
Diameter of the artery (mm) [median (IQR)]	1.0 (0.7–1.0)	1.0 (0.8–1.0)	*P* = 0.71	
Vein graft (yes/no) (%)	47 (51.6)/44 (48.4)	14 (17.1)/68 (82.9)	*P* < 0.05	2.44–11.36
Warm ischemic time [median (IQR)]	469.0 (405.5–576.0)	522.5 (419.3–618.5)	*P* = 0.20	
Success/failure (%)	74 (81.3)/17 (18.7)	59 (72.0)/23 (28.0)	*P* = 0.15	0.78–3.71

IQR, interquartile range; T, thumb; I, index finger; M, middle finger; R, ring finger; L, little finger; complete, complete amputation; incomplete, incomplete amputation; single, single-digit amputation; multiple, multiple digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

amputation group. Univariate analyses revealed fewer multiple amputations and more vein grafts in the revascularization subgroup than in the replantation subgroup. We found no statistically significant differences except for these variables. No variables showed a significant difference between the proximal revascularization subgroups with and without vein anastomosis (Table 7). There were no cases of vein grafting to the veins in the revascularization subgroup.

In multivariable logistic regression analyses, to adjust each variable, we selected "fracture," "mechanism," and "the artery diameter" as explanatory variables. Variables that showed statistically significant differences in the univariate analysis remained statistically significant differences in the multivariable analysis (Table 8).

DISCUSSION

The success rate of revascularization has been reported to be similar to or higher than that of replantation due to venous return.[7–10] However, intact venous return is not necessarily secured with revascularization in severe cases.

The characteristics of distal and proximal amputations were not similar. The arterial diameter was smaller in the distal amputation group; there were more severe cases in the proximal amputation group than in the distal amputation group. However, these groups had no statistically significant difference in the success rate. The severity of the injury was lower in the distal amputation group than that in the proximal amputation group, possibly because the arteries of the amputated digit were severely damaged or too short to be identified, secured, or anastomosed in

Table 7. Univariate Associations between Proximal Incomplete Amputation with and without Vein Anastomosis

Variable	No Vein Anastomosis	Vein Anastomosis	Results of Univariate Analysis	
	Digit = 76	Digit = 15	*P*	95% CI
Single/multiple (%)	49 (64.5)/27(35.5)	12 (80.0)/3 (20.0)	*P* = 0.37	0.08–1.90
Fracture (none or simple/comminuted) (%)	55 (72.4)/21 (27.6)	14 (93.3)/1 (6.7)	*P* = 0.1	0.00–1.40
Mechanism (guillotine/avulsion or crush) (%)	41 (53.9)/35 (46.1)	10 (66.7)/5 (33.3)	*P* = 0.41	0.14–2.11
Success/failure (%)	59 (77.6)/17 (22.3)	14 (93.3)/1 (6.7)	*P* = 0.29	0.01–1.89

Single, single-digit amputation; multiple, multiple digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

Table 8. Multivariable Associations between Revascularization and Replantation Subgroups of Proximal Fingers

Variable	Results of Multivariable Analysis		Results of ROC Analysis				
	P	OR (95% CI)	AUC	95% CI	Cutoff Value	Sensitivity	Specificity
Sex (male/female)	*P* = 0.07	0.14 (0.02–1.19)					
Age, year	*P* = 0.99	1.00 (0.98–0.99)	0.53	0.42–0.63	71.00	0.89	0.21
Comorbidity (yes/no)	*P* = 0.17	0.39 (0.10–1.51)					
Active smoker (yes/no)	*P* = 0.92	0.96 (0.47–1.96)					
Side (right/left)	*P* = 0.22	1.56 (0.76–3.20)					
Single/multiple	*P* < 0.05	2.27 (1.18–4.35)					
Vein graft (yes/no)	*P* < 0.05	0.17 (0.08–0.38)					
Warm ischemic time	*P* = 0.37	1.00 (1.00–1.00)	0.56	0.48–0.65	538.00	0.85	0.29
Success/failure	*P* = 0. 06	2.09 (0.97–4.50)					

ROC: receiver operatorating characteristic; AUC: area under the curve; T: thumb; I: index finger; M: middle finger; R: ring finger; L: little finger; complete, complete amputation; incomplete, incomplete amputation; single, single-digit amputation; multiple, multiple digit amputation; none, no fracture; simple, simple fracture; comminuted, comminuted fracture; guillotine, guillotine amputation; avulsion, avulsion amputation; crush, crush amputation.

severe cases of the distal amputation group.[16] We assumed that cases with severe damage may have been excluded by amputation plasty.[16] It was hypothesized that potential selection bias in avoiding distal arterial anastomosis could be attributed to smaller arterial diameters. However, in the proximal amputation group, it could be associated with multiple amputations and the severity of injuries.

There were no significant differences between the subgroups of the distal amputation group in success rates, and the arterial diameter was larger in the distal revascularization subgroup than in the distal replantation subgroup; however, vein grafts were applied more frequently in the distal revascularization subgroup. Kobayashi et al reported that cohorts of amputations having a higher frequency in applying vein grafts include more severe cases.[16] This suggests that the severity in the revascularization subgroup was either similar to or greater than that in the replantation subgroup. It also indicated that there was no bias in avoiding severe cases in the distal revascularization subgroup.

Conversely, between the subgroups of the proximal amputation group, there were no statistically significant differences in the success rates and variables of severe cases such as comminuted fracture, avulsion, and crushed amputation. However, multiple-digit amputation was less frequent in the revascularization subgroup than in the replantation subgroup, and vein grafting was performed more frequently in the revascularization subgroup. This also indicated that the severity of the proximal revascularization subgroup was similar to or greater than that of the replantation subgroup.[16] This finding also indicated that there was no bias in avoiding severe cases within the proximal revascularization subgroups.

As mentioned above, both revascularization subgroups had similar severity and success rates compared with the replantation subgroups. The results indicated that the skin bridge might not have secured sufficient venous drainage in the revascularization subgroups with damaged soft tissues, although there was skin continuity. If severe cases were excluded from the cohort of both the revascularization and replantation subgroups, the success rate of the revascularization subgroup would be higher than that of the replantation subgroup due to reliable venous drainage, as described in previous reports.[7–11]

It is often difficult to determine if the skin bridge has sufficient venous return at the time of the injury. There was no statistical difference in the variables indicating the severity between the revascularization subgroups with and without vein anastomosis; however, it would be safer to anastomose veins where insufficient circulation of the skin bridge is suspected. There were no cases of vein grafting to the veins in the revascularization subgroups. However, this study also indicated that vein grafting to the vein is desirable in cases of incomplete amputation with severe injury, although vein grafting to the vein in incomplete amputation without damaging the skin bridge might be a difficult maneuver.

This study has several limitations. First, it was a retrospective study. Second, the division of fracture types and mechanisms was subjectively decided by each surgeon. The application of an interpositional vein graft was also determined by each surgeon, depending on the situation and could not be prospectively controlled. Therefore, other potential surgical predictors could not be identified. Third, we did not investigate cases of amputation in which replantation or revascularization was avoided. Fourth, there were few cases of vein grafting to the veins. Finally, the study's outcome was determined by survival or failure without considering the functional, aesthetic, and patient-related outcomes of replantation or revascularization. Further prospective studies are required to generalize these findings.

Despite its limitations, the present study indicates that the higher success rate of revascularization compared with that of replantation might be due to bias in avoiding severe cases. In addition, vein anastomosis or vein grafting to the veins should be advocated for revascularization in severe incomplete amputations.

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DISCLOSURE

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