OPEN

PRS GLOBAL OPEN

ORIGINAL ARTICLE
Hand/Peripheral Nerve

Composite Grafts for Pediatric Fingertip Amputations: A Retrospective Case Series of 100 Patients

Mimi R. Borrelli, MBBS, MSc, BSc*
Sophie Dupré, BSc*
Saniya Mediratta, BSc†
Alessandra Bisquera, MSc‡
Aina Greig, MA, PhD, FRCS(Plast)*

Background: Fingertip amputations are common. This study reports on the outcomes of composite grafts used for fingertip amputations in children, measuring graft take, predictors of graft take, complications, and patient-reported outcomes.
Methods: A retrospective case series of consecutive patients (≤ 16 years) undergoing composite grafts for fingertip amputations in a tertiary pediatric hospital, January 06 to December 16, was performed. Information was collected on amputations, graft take, and complications. Logistic regression was used to analyze factors predicting graft take (partial/complete or failure) including age; amputation level; mechanism and time delay to surgery. Patients were contacted via post or telephone to ask about functional and cosmetic outcomes and their perception of graft take.
Results: One hundred patients [57 (57%) males; mean age, 4.41 ± 3.98 years], presenting with 100 fingertip amputations, met the inclusion criteria. Amputation mechanism was crush in 75 (75%), avulsion in 13 (13%), and laceration in 12 (13%). Thirteen (13%) composite grafts survived completely, 46 (46%) partially, and 41 (41%) failed. Graft survival was higher in children under 4 years ($P = 0.016$). Seventeen (17%) grafts became infected, 9 (9%) required a reoperation, 9 (9%) had wound healing complications, and 4 (4%) patients developed psychological complications. Patient-reported survival was 33% higher than medical-reported survival. Cosmetic issues were the commonest complication reported by patients. Patients rated fingertips looking 3.5/5 normal, and that they were 4/5 satisfied with the appearance. Most patients were using their fingers normally by 2–6 months.
Conclusions: Composite grafts for fingertip amputations mostly only partially survive, but morbidity is low, patient satisfaction is high, and acceptable cosmetic and functional outcomes are achieved. *(Plast Reconstr Surg Glob Open 2018;6:e1843; doi: 10.1097/GOX.0000000000001843; Published online 19 June 2018.)*

INTRODUCTION

Fingertip amputations are common in children, often occurring after crush injuries in doors[1,2] (Fig. 1). When there are no available vessels for anastomosis, a composite graft may restore cosmetic appearance, digit length, fingertip function, and sensation. Composite graft survival rates are highly variable, ranging from 0% to 93.5%[3,4] with little consensus over the factors predictive of graft success, from amputation-reattachment delay, amputation mechanism and level, age, smoking, and operative technique.[5–8] The key complications are infection and necrosis.[4–20] In the pediatric population, composite grafting requires a general anesthetic in most cases.[7] Some argue losing a single fingertip minimally affects hand function, and no reattachment may be necessary at all.[21,22] It is still unclear whether composite grafting is a worthwhile technique.

At our institution, composite grafting for pediatric fingertip amputations is a commonly performed procedure, but the outcomes of these grafts have not previously been

*From the *The Plastic Surgery Department, Guy's and St Thomas Hospital, London, United Kingdom; †Imperial College, School of Medicine, South Kensington Campus, London, United Kingdom; and ‡School of Population Sciences and Health Services Research, Faculty of Life Sciences and Medicine, King's College London, United Kingdom.*

Received for publication March 9, 2018; accepted May 4, 2018.

No ethical approval required for audit/retrospective case series. Approval from the audit was obtained. Audit registration number: 6799.

DOI: 10.1097/GOX.0000000000001843

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by Imperial College London.*

Supplemental digital content is available for this article. Clickable URL citations appear in the text.

Fig. 1. Young child with right little fingertip amputation after a crush injury, where the finger-tip was caught in a door.

assessed. This study aimed to report our clinical experience with composite grafts, assess their success in terms of graft take and complications, determine the factors that predict graft survival, and analyze the association between patient-reported cosmetic, functional, sensory outcomes, and patient-reported graft survival.

METHODS

A retrospective review of consecutive patients, ≤ 16 years, who underwent composite grafting of fingertip amputations (distal to the distal interphalangeal joint of the fingers or the interphalangeal joint of the thumb), performed between January 01 2006 and 31 December 2016 at The Evelina, a tertiary pediatric teaching hospital in London, was undertaken. Approval was obtained from the hospital's institutional review board. Reporting is in accordance with PROCESS guidelines.[23] Patients were excluded where there was no follow-up data available, or if they had multiple fingertip amputations. Information was collected on demographics; amputation and operative details; primary and secondary outcomes (Table 1). Data were collected into a preformed Microsoft Excel 2011 database (Microsoft, Redmond, Wash.), and anonymized.

Definitions

The mechanism of amputation was recorded, adopting Biemer's[24] definitions, as: laceration—from a sharp object with no loss of tissue and minimal crushing; crush—from a blunt object with some loss and crushing of tissues; avulsion—from severe crushing or avulsion of tissues. The amputation level was categorized using the Modified-Ishikawa classification[5] (Fig. 2) when transverse, and as "oblique" when oblique (Fig. 3). Amputation level was determined from pictures or written descriptions. Amputations were also categorized as: complete—fully amputated tip; or partial—amputated tip attached by either vasculature, bone, or skin. Distinction was made between patients directly admitted to the emergency department and those transferred from another institution

Table 1. Patient Demographic, Amputation, Operative and Admission Details

No. patients (N)	100*			
No. fingertips (N)	100*			
Fingertip injured	LLF: 14 (13%) LRF: 12 (12%), LMF: 12 (12%), LIF: 5 (5%), L thumb: 4 (4%), RLF: 17 (17%) RRF: 12 (12%), RMF: 9 (9%), RIF: 13 (13%), R thumb: 2 (2%)			
Age (y, mean ± SD)	4.41 ± 3.98 y (range, 0.08–15.83)			
	Under 4 y: 65 (65%)		Over 4 y: 35 (35%)	
Sex N(%)	Males: N = 57 (57%)		Females: N = 43 (43%)	
Comorbidities	1 (1%) sickle cell disease	1 (1%) HIV +ve		1 (0.98%) presented after NAI
Referral source, N (%)	Direct: 27 (27%)		Transfer: 73 (73%)	
Time delay to presentation (h)	< 6 hours: 25 (25%)		6 hours: 74 (74%) 6–12 h: 51 (51%) 12–24 h: 17 (17%) > 24 h: 6 (6%)	
Mechanism of injury, N (%)	Crush: 75 (75%)	Avulsion: 13 (13%).		Laceration: 12 (12%)
Degree of amputation	Partial: 19 (19%)	Complete: 81 (81%)		
Storage of amputated part	Cooled: 81 (81%)	Not cooled: 19 (19%)		
Amputation level	Transverse: 87 (87%)	1a: 3 (3%) 1b: 26 (26%) 2: 42 (42%) 3: 16 (16%)		Oblique: 13 (13%)
Fracture present	Present: 29 (29%)			Absent: 64 (64%)
Bone exposed	Exposed: 60 (60%)			Not exposed: 36 (36%)
Anesthetic	GA: 85 (85%)	LA: 6(6%)		Sedation: 2(2%)
Tourniquet time mean ± SE (min)	23.8 ± 5.56 (used/reported in N = 14 patients)			
Graft survival	Complete: 13(13%)	Partial: 46(46%)		Fail: 41(41%)
	Survival (complete/partial): 29 (59%)			Fail: 41 (41%)
Infection	Yes: 17 (17%)	No: 83 (83%)		
Reoperation	Yes 9 (9%)	No: 91 (91%)		
Psychological	Yes 4 (4%)	No: 96 (96%)		
Wound healing	Yes: 9 (9%)	No: 91 (91%)		
Length of hospital stay (d)	0 days: 37 (37%)	1 day: 61 (61%)		2 days: 2 (2%)
Follow-up, mean ± SD (mo)	4.65 ± 10.85 (range, 0.5–96)			

*Details reported on 100 digits in 100 patients except for anesthetic mechanism (N = 93 patients), time delay (N = 99 patients), bone exposed (N = 96 fingertips), bone fracture (N = 93 fingertips).

GA, general anesthesia, L, left; LA, local anesthesia; LIF, left index finger; LLF, left little finger; LMF, left middle finger; LRF, left ring finger; N, number; NAI, nonaccidental injury; R, right; RIF, right index finger; RLF, right little finger; RMF, right middle finger; RRF, right ring finger.

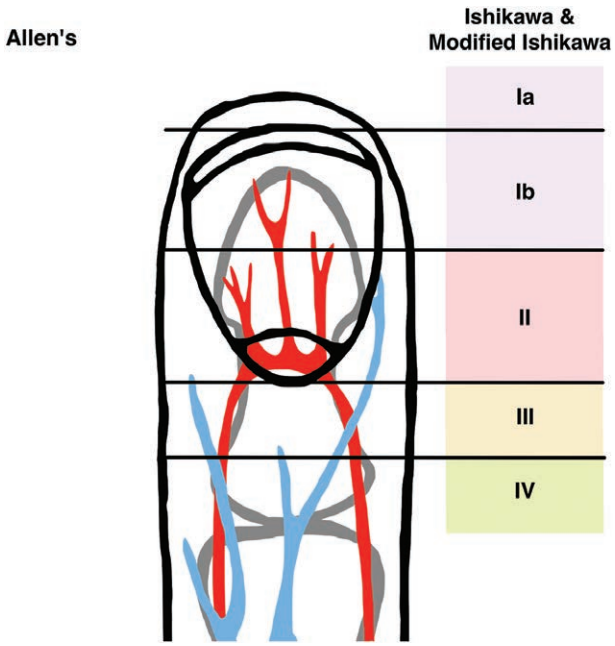

Fig. 2. Ishikawa[26] distal fingertip zones: I - beyond mind-nail; II – between mid-nail and nail base (eponychium); III –midway between eponychium and DIPJ; IV – between II and DIPJ. Moiemen and Elliot[5] divided category I into: Ia – beyond the distal edge of the nail; and Ib – between the mid-nail and distal edge of the nail.

(direct versus transfer). Time delay from injury to surgery was categorized as greater than or less than 6 hours, and into 6-hour time slots.

The primary outcome was graft survival, categorized as complete, partial, or failure, using definitions described by Butler et al.[8] (Table 2). Graft take was determined through pictures and written description from the dressing clinic visit, 7–14 days after surgery. Secondary outcomes included complications (psychological, wound healing, infection, reoperation); and follow-up (time from surgery until the last plastic surgery out-patient or dressing clinic appointment).

Composite Grafting Technique for Fingertip Amputations

The overall surgical technique was consistent for all patients, with small variations depending on the nature of the injury, performed by the plastic surgeon on-call. Fingertips were minimally debrided and thoroughly irrigated. Exposed bone was nibbled. Some "defatting" of the composite grafts was performed in 22 (22%) patients. The nail plate, when present, was removed and replaced as a splint at the surgeon's discretion. The amputated part was inset using absorbable interrupted sutures.

Questionnaire

A questionnaire was designed to ask patients/parents about the aesthetic, sensory, and functional outcomes of the graft, and their impression of graft survival (Table 3). It was sent in the post and followed up with a telephone call if no response was returned.

Statistics

All statistical analyses were performed on SPSS (version 23.0, Chicago, Ill.). A P-value < 0.05 was considered statistically significant. The sample size was chosen to recruit similar numbers of patients to the largest previous audits conducted[7,8]; therefore, an 11-year retrospective window was chosen. For the purpose of statistical analysis, partial and complete survival were grouped into a single category, to increase statistical power and allow binary logistic regression to be performed.

Continuous data were described with means and SDs when parametric, and with medians and ranges when nonparametric. Data were reported as frequencies when categorical. The Mann-Whitney U test was used to compare nonparametric continuous data (2-sided). The chi-square test was used to assess association between categorical variables; the fishers exact test was used when frequencies were less than 5.

Multivariable logistic regression analyses were performed to determine factors predictive of graft survival and graft infection. Factors significant at $P = 0.25$ in univariable analyses were entered into multivariable analyses. Regressions were repeated excluding partial amputations for sensitivity analyses.

RESULTS

Of the 113 patients who underwent composite grafting over the 11-year period, 100 patients, with 100 fingertips, met the inclusion criteria [mean age, 4.41 ± 3.98 years (range, 0.08–15.8), males: 57 (57%), Table 1]. Most amputations followed crush injuries [N = 75 (75%)], occurred at Modified-Ishikawa level II [N = 42 (42%)], and involved exposed bone [N = 60 (60%)]. Thirteen (13%) amputations were oblique, and 29 (29%) had an associated fracture. Nineteen (19%) amputations were partial, where the tip was held on by a skin tag (N = 14), bone in a

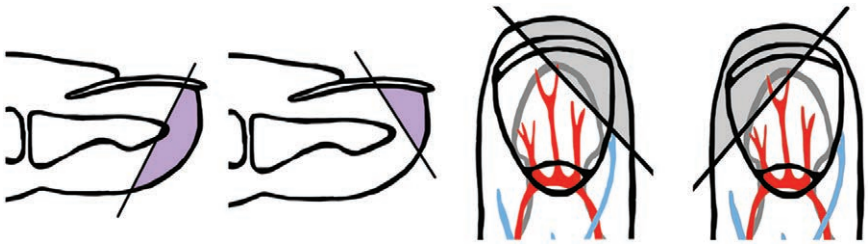

Fig. 3. Dorsal-oblique (far left), volar-oblique (middle left), lateral oblique (far and middle right) fingertip amputations.

Table 2. Definitions of Graft Success

Fail	No viable tissue of the replanted tip
Partial	Any graft for which there were patches of necrotic tissue interspersed with viable tissue
Complete	No areas of necrosis at follow-up

Table 3. Patient/Parental Questionnaire: Fingertip Repair Surgery

Did the fingertip survive?
☐ Yes/☐ no
Is the sensation of the fingertip:
☐ normal/☐ reduced/☐ increased
Have you experienced any of the following discomforts after the operation:
☐ Numbness
☐ Tender fingertip or tender scar
☐ Pain in the fingertip in cold weather
Does the fingertip look normal? (please circle)
(completely abnormal) 0 – 1- -2- -3- -4- -5 (completely normal)
is the fingertip shorter that it was?
☐ Yes, *if yes, how much shorter* _____*mm*
☐ No
Is the nail growth normal?
☐ Yes
☐ No, *if no* is the nail ☐ absent, ☐ curved round abnormally,
☐ shortened
How satisfied are you with how the injured finger looks now? (please circle)
(not at all satisfied) 0 – 1 – 2 – 3 – 4 – 5 (completely satisfied)
Roughly how long (months or days) was it before you/your child was using his/her finger in normal activities?
☐ 1–2 weeks, ☐ 2–4 weeks, ☐ 1–2 months, ☐ 2–6 months,
☐ >6 months
Who was the main person answering this survey?
☐ Parent/guardian, ☐ Child, ☐ both
Did you feel fully informed about the outcomes of the surgery?
☐ Yes, definitely, ☐ Yes, to some extent, ☐ No
Any additional comments?

circumferential laceration (N = 2) or by neurovasculature (N = 3). All the completely amputated tips, but none of the partially amputated tips, had documented preoperative cooling. Seventy-five (75%) patients were transferred from another hospital. Twenty-five (25%) were operated on within 6 hours of injury (Fig. 4), but most operations took place 6–12 hours after the injury (N = 51, 51%). Patients directly admitted were more likely to have surgery within 6 hours [11/2 6 (42.3%) versus 14/75 (18.7%), $P = 0.016$].

The overall surgical technique was consistent for all patients, with small variations depending on the nature of the injury, performed by the plastic surgeon on-call, as previously described. A Kirschner wire was used to fix 1 proximal fracture. Microvascular replantation was attempted in 1 case, but reverted to composite grafting after 90 minutes. Six (6%) fingers were splinted. General anesthesia was administered to 85 (85%) patients. A finger or arm tourniquet was used in 14 patients (mean tourniquet time, 23.8 ± 5.56 minutes). There were no operative complications. All patients were discharged with a 5- or 7-day course of oral antibiotics. Sixty-one (61%) patients stayed 1 night in hospital. Dressings were applied and changed in dressing clinic after 2–5 days. Average follow-up was 4.65 ± 10.85 months (range, 0.5–96).

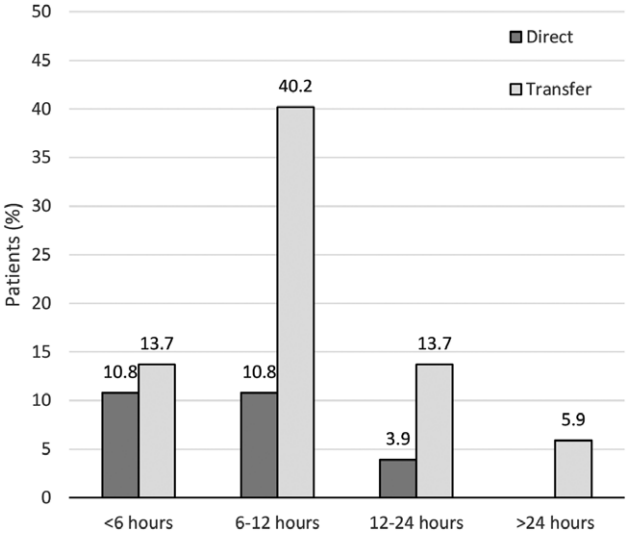

Fig. 4. Time delay to surgery stratified by whether patients were direct vs. transfer admission. Numbers show the percentage of patients in each category (N = 99).

Graft Survival and Factors Associated with Graft Survival

Thirteen (13%) composite grafts survived completely, 46 (46%) partially and 41 (41%) failed (Table 1). Composite grafts were more likely to survive in children under 4 years old versus over in univariable [44/65 (67.7%) versus 15/35 (42.9%), $P = 0.016$, Table 4] and multivariable analysis [odds ratio (OR), 2.495; 95% CI, 1.026–6.062, $P = 0.044$, Table 5]. Univariable analysis indicated a significant effect of injury mechanism on graft survival: 26/75 (34.7%) crush; 3/13 (23.1%) avulsion and 7/12 (58.3%) laceration injuries survived ($P = 0.016$). In multivariable analysis, crush injuries were more likely to survive than avulsion injuries (OR, 5.430; 95% CI, 1.336–22.078; $P = 0.018$). When partial amputations were excluded, only avulsion injuries were more likely to fail than crush injuries (OR, 5.390; 95% CI, 1.287–22.580; $P = 0.021$; Table 6). There was no survival difference at different amputation levels (though none of the 3 level Ia amputations failed), between complete or partial amputations, oblique or transverse amputations, or those involving a fracture or exposed bone. There was no survival benefit of fingertips operated on before 6 hours (though no repairs after 24 hours survived).

Complications

The mean clinic follow-up time was 4.5 months (standard error [SE], 1.03). Seventeen (17%) grafts became infected. Swab results, reported in 9, revealed growth of *Staphylococcus aureus* (N = 4), Gram-negative organisms (N = 3) and skin flora (N = 2). In univariable analysis (Table 7), no factors were associated with graft infection. In multivariable analysis (Table 8), grafts of children under 4 (OR, 5.096; 95% CI, 1.073–24.208; $P = 0.041$) and following amputations with exposed bone (OR, 3.402; 95% CI, 1.020–11.349; $P = 0.046$) were more likely to become infected, and infected grafts were more likely to fail (OR, 3.703; 95% CI, 1.105–12.410; $P = 0.034$). All

Table 4. The Association of Demographic Information and Characteristics of Injured Digits with Graft Survival, in 100 Patients with 100 Fingertips*

Characteristics	Failed (N = 41)	%	Complete/ Partial (N = 59)	%	*P*
Age at surgery (y)					
< 4	21	32.3	44	67.7	
4	20	57.1	15	42.9	0.016
Sex					
Males	25	43.9	32	56.1	
Females	16	37.2	27	62.8	0.503
Presentation					
Direct	9	33.3	18	66.7	
Transfer	32	43.8	41	56.2	0.343
Time delay (h)					
< 6	12	48	13	52	
> 6	29	39.2	45	60.8	0.439
Mechanism of injury					
Crush	26	34.7	49	65.3	
Avulsion	10	76.9	3	23.07	
Laceration	5	41.7	7	58.3	0.016
Fracture present					
Yes	14	48.3	15	51.7	
No	26	40.6	38	59.4	0.490
Level					
1a	0	0	3	100	
1b	12	46.2	14	53.8	
II	16	38.1	26	61.9	
III	8	50	8	50	
Oblique	5	38.5	8	61.5	0.621
Fracture type					
Oblique	5	38.5	8	61.5	
Transverse	36	41.4	51	58.6	0.842
Degree					
Partial	6	31.6	13	68.4	
Complete	35	43.2	46	56.8	0.354
Bone exposed					
Yes	25	41.7	35	58.3	
No	15	41.7	21	58.3	1.00

*For the purpose of statistical analysis, partial and complete survival categories are grouped together in a single category of "survival." Chi-square used for all statistical comparisons except where frequencies were < 5, in which case Fisher's exact test was used. All statistical comparisons N = 100 except for missing data for time delay (N = 99), presence of fracture (N = 93), bone exposure (N = 96).
N, number.

Table 5. Analysis of Factors Associated with Composite Graft Take Using a Multivariate Logistic Regression Analysis in N = 100 Patients with N = 100 Fingertip Amputations

Factors	*P*	OR	95% CI	Reference
Age (< 4/> 4 y)	0.044	2.495	1.026–6.062	> 4 y
Injury mechanism: avulsion	0.060			Avulsion
Injury mechanism: crush	0.018	5.430	1.336–22.078	Avulsion
Injury mechanism: laceration	0.080	4.849	0.828–28.393	Avulsion

CI, confidence interval, OR, odds ratio.

Table 6. Analysis of Factors Associated with Composite Graft Take Using a Multivariate Logistic Regression Analysis in N = 81 Patients with N = 81 Complete Fingertip Amputations

Factors	*P*	OR	95% CI	Reference
Age (< 4/> 4 y)	0.103	2.219	0.852–5.779	> 4 y
Injury mechanism: avulsion	0.065			Avulsion
Injury mechanism: crush	0.021	5.344	1.294–22.066	Avulsion
Injury mechanism: laceration	0.081	5.141	0.817–32.365	Avulsion

CI, confidence interval; OR, odds ratio.

Table 7. The Association of Demographic Information and Characteristics of Injured Digits with Graft Infection, in 100 Patients with 100 Fingertips*

Characteristics	Infection (N = 20)	%	No Infection (N = 80)	%	*P*
Age at surgery (y)					
< 4 y	14	21.5	51	78.5	
> 4 y	3	8.6	32	91.4	0.082
Sex					
Males	11	19.3	46	80.7	
Females	6	14.0	37	86	0.481
Presentation					
Direct	3	11.1	24	88.9	
Transfer	14	19.2	59	80.8	0.263
Time delay (h)					
< 6	2	8	23	92	
> 6	15	20.3	59	79.7	0.134
Mechanism of injury					
Crush	13	17.3	62	82.7	
Avulsion	2	15.4	11	84.6	
Laceration	2	16.7	10	83.3	1.000
Fracture present					
Yes	6	20.7	23	79.3	
No	10	15.6	54	84.4	0.549
Level					
1a	0	0	3	100	
1b	3	11.5	23	88.5	
II	10	23.8	32	76.2	
III	1	6.3	15	93.7	
Oblique	3	23.1	10	76.9	0.451
Amputation type					
Oblique	3	23.1	10	76.9	
Transverse	14	16.1	73	83.9	0.385
Degree					
Partial	4	21.1	15	78.9	
Complete	13	16.0	68	84.0	0.410
Bone exposed					
Yes	8	13.3	52	86.7	
No	9	25	27	75	0.147
Graft success					
Complete/partial	7	11.9	52	88.1	
Failure	10	24.4	31	75.6	0.101

*For the purpose of statistical analysis, partial and complete survival categories are grouped together in a single category of "survival." Chi-square used for all statistical comparisons except where frequencies were < 5, in which case Fisher's exact test was used. All statistical comparisons N = 100 except for missing data for time delay (N = 99), presence of fracture (N = 93), bone exposure (N = 96).
N, number.

Table 8. Analysis of Factors Associated with Graft Infection Using a Multivariate Logistic Regression Analysis in N = 100 Patients with N = 100 Fingertip Amputations

Factors	*P*	OR	95% CI	Reference
Time (< 6, > 6 h)	0.301	0.422	0.082–2.166	> 6 h
Age (< 4, > 4 y)	0.041	5.096	1.073–24.208	> 4 y
Bone exposed	0.046	3.402	1.020–11.349	Exposed
Survival	0.034	3.703	1.105–12.410	Survived

ß, partial regression coefficient; CI, confidence interval; OR, odds ratio.

associations remained when partial amputations excluded (**See table, Supplemental Digital Content 1**, which displays analysis of factors associated with composite graft take using a multivariate logistic regression analysis, ***http://links.lww.com/PRSGO/A797***).

Nine (9%) patients returned to theatre: 5 (5%) for debridement of infected or necrotic material and 4 (4%) for

Fig. 5. Child with right middle finger tip composite graft with over granulation.

terminalization due to exposed bone. Failed grafts were more likely to undergo a second operation [8/35 (22.9%) versus 1/46 (2.17%), $P = 0.003$]. Nine (9%) patients had wound healing complications, most commonly overgranulation (Fig. 5). Four (4%) patients developed psychological complications. One patient (8.17 years) developed hypersensitivity and phantom pain following a failed graft and terminalization, requiring psychological and occupational therapist input. One patient (8.58 years) developed a hook nail and posttraumatic stress disorder. Another patient (3.5 years) developed anxiety as her finger was used by others to differentiate between herself and her identical twin. The last patient (3 years) prevented anyone looking at her finger and used foil as a pretend nail.

Questionnaire Data

The questionnaire response rate was 50% (51/102), answered mostly by parents [N = 41 (80.4%), Table 9]. The mean questionnaire postoperative follow-up time was 41.3 months (SE, 4.89). Patient-reported graft survival was 78.4% (40/51), 33% more than the survival rates reported by the medical team in these same patients [58.8% (30/51)]. Patient- and medical-reported survival were associated ($P = 0.02$, Table 9). Forty-five (88.2%) patients felt well informed before surgery. Sensory problems were reported in 16–30% patients, and most common was a tender fingertip/scar (N = 15, 29.4%). Eight (15.7%) reported numbness and 9 (17.6%) pain in cold weather. There was no association between altered sensation, numbness, tenderness, or pain in cold weather and patients' perception of graft survival (Table 10). Over half the patients reported changes to fingertip cosmesis, including finger shortening (N = 29, 56.9%) by an average of 3.93±2.84 mm (range, 1–10) and nail growth abnormalities (N = 26, 51%). Patients rated fingertips looking on average 3.5/5 "normal" in appearance (Fig. 6), but rated themselves on average 4/5 (range, 0–5) satisfied with the cosmetic appearance (Fig. 7). Patients/parents who perceived the graft to fail reported their finger had abnormal nail growth [10/11 (90.9%) 15/40 versus 15/40 (37.5%), $P = 0.002$], looked more abnormal (U = 56.5, $P < 0.001$) and were less satisfied with the cosmetic outcome (U = 56.5, $P < 0.001$). Most patients reported it took 2–6 months before repaired fingertips/hands were used in normal daily activities (Fig. 8). Healing time had no association with perceived graft survival.

DISCUSSION

In this study, the most likely outcome of the composite grafts was partial survival, a finding consistent across the literature (Table 11). The complete graft survival rate (13.3%) and partial graft survival rate (44.8%) in our study were similar to the mean rates after our meta-analysis [14.6% (range, 7.7–22%) for complete survival and 49.2% (range, 34–59%) for partial survival, respectively; Table 11]. Children under 4 years of age had a higher chance of composite graft survival than children over 4. Four was chosen as a cutoff age following Butler et al.,[8] who stratified patients into 3-yearly age groups and found a higher chance of graft survival in children under 4 years of age. Other studies have not supported a

Table 9. Patient and Parent-reported Outcomes of the Amputated Tip (N = 51)

Outcome Measure	Outcomes		
Fingertip survival*	Yes: 40 (78.4%)	No: 11 (21.6%)	
Sensory outcomes			
Sensation	Normal: 27 (52.9%)	Increased: 10 (19.6%)	Reduced: 14 (27.5%)
Cold intolerance	Yes: 9 (17.6%)	No: 42 (82.4%)	
Numbness	Yes: 8 (15.7%)	No: 43 (84.3%)	
Tender tip/scar	Yes: 15 (29.4%)	No: 36 (70.6%)	
Cosmetic outcomes			
Normal appearance rating	Median 3.5/5 (range, 0–5)		
Finger shortening*	Yes: 29 (56.9%)	No: 21 (41.2%)	
	Average shortening (mm): 3.93±2.84 mm (range, 1–10)		
Normal nail growth	Yes: 26 (51.0%)	No: 25 (49%)	
Abnormal curve of nail	Yes: 19 (37.3%)	No: 32 (62.7%)	
Nail shortening	Yes: 47 (92.2%)	No: 4 (7.8%)	
Absent nail	Yes: 3 (5.9%)	No: 48 (94.1%)	
Satisfaction with appearance	Median: 4/5 (range, 0–5)		
Functional outcomes			
Time before using hand/finger in normal activities	1–2 wk: 3 (5.9%) 2–6 mo: 18 (35.3%)	2–4 wk: 11 (21.6%) > 6 mo: 9 (17.6%)	1–2 mo: 10 (19.6%)
Felt fully informed	Yes definitely: 38 (74.5%)	Yes to some extent: 7 (13.7%)	No: 6 (11.8%)
Who answered	Parent: 41 (80.4%)	Child: 4 (7.8%)	Both: 6 (11.8%)

*All questions were answered by 51 patients except for "shortening" (N = 50) and "satisfaction with appearance" (N = 49).

Table 10. Association between Outcomes (Cosmetic, Functional, Sensory) and Medical Graft Survival with Patient-reported Graft Survival (N = 51)

Characteristics	Success (N = 40)	%	Failure (N = 11)	%	*P*
Sensation					
Normal	22	81.5	5	18.5	
Increased	11	78.6	3	21.4	
Reduced	7	70	3	30	0.745
Numbness					
Yes	5	62.5	3	37.5	
No	35	81.4	8	18.6	0.226
Tenderness					
Yes	10	66.7	5	33.3	
No	30	83.3	6	16.7	0.187
Pain in cold weather					
Yes	4	44.4	5	55.6	
No	36	85.7	6	14.3	0.015
Finger shortening					
Yes	20	69.0	9	31.0	
No	19	90.5	2	9.5	0.068
Normal nail growth					
Yes	25	96.2	1	3.8	
No	15	60	10	40	0.002
Absent nail					
Yes	0	100	3	100	
No	40	83.3	8	16.7	0.008
Curved nail					
Yes	13	68.4	6	31.6	
No	27	84.4	5	15.6	0.180
Short nail					
Yes	3	75	1	25	
No	37	78.7	10	21.3	0.634
Time before use					
1–2 wk	3	100	0	0	
2–4 wk	8	72.7	3	27.3	
1–2 mo	7	70	3	30	
2–6 mo	16	88.9	2	11.1	
> 6 mo	6	66.7	3	33.3	0.524
Felt well informed					
Definitely	31	81.6	7	18.4	
To some extent	5	71.4	2	28.6	
No	4	66.7	2	33.3	0.619
Medically reported graft success					
Complete/partial	27	90	3	10	
Failure	13	61.9	8	38.1	0.020

*Chi-square used for all statistical comparisons except where frequencies were < 5, in which case Fisher's exact test was used. All statistical comparisons N = 51 except for finger shortening (N = 50).
N, number.

significant impact of age on graft success,[6,7,18,19,25] but all these studies used different populations or age categories. Crush injuries were more likely to fail than avulsion injuries, a finding not previously reported in composite grafts; however, avulsion injuries are commonly cited as having poor functional outcomes after replantation due to the extensive damage to skin, nerves, and vessels in such injuries.[26] Some authors have reported laceration injuries have higher graft survival than crush and avulsion injuries[6,11,18]; this trend did not reach significance here, likely because of the small numbers of laceration injuries.

Time delay from injury to surgery has been identified as a factor potentially affecting graft survival. In this series, patients were treated in a tertiary pediatric hospital, with 75% having been transferred from another hospital. Due to time elapsed in the work-up to surgical intervention, 75% of patients were operated on after 6 hours. Although only a small group of patients were operated on directly and before 6 hours, no difference in outcomes between transfer patients and direct admissions was found in this study, replicating findings by Eberlin et al.[25] On the other hand, Moiemen and Elliot[5] found that amputations repaired as composite grafts more than 5 hours after amputation were less likely to survive. This 5-hour cutoff point; however, was later criticized for being arbitrary and not the classic 6-hour "ischemic" time and not identified as independent predictor of graft success in logistic regression,[25] with 2 subsequent larger case series failing to replicate the findings.[7,8] Due to the retrospective nature of this study, it was difficult to assess the actions taken in the interim period before surgery; however, it has been noted that quick replacement of the fingertip immediately after injury could contribute to improved graft survival.[25] There was also no difference in graft take between grafts replaced before or after the 6 hour "ischemic" time. Six hours has been identified as the time after which devascularised muscle undergoes irreversible ischemic damage.[25] Fingertip composite grafts are mostly skin and fat which can tolerate up to 24 hours of cold ischemia time in finger replantations.[27,28] Of note, none of the fingertips operated on after 24 hours in this study survived. Most of the amputated tips were cooled before application as a composite graft. Cooling decreases tissue metabolic demands without causing damage and exhibits a bacteriostatic effect. Assuming the accuracy of documented preoperative cooling, this suggests that time may have little effect on graft survival up to 24 hours before surgery if grafts are appropriately cooled preoperatively.

Although all 3 level Ia amputations survived completely, amputation level was not a significant predictive factor of graft survival. Some authors report that amputations at level Ia[8] or I[11] are more likely to survive than those more proximal. Others, however, reported no effect of amputation level on survival.[7,18] This study compared survival between "oblique" and transverse amputations. Oblique amputations may potentially lead to improved graft take due to a much larger surface area of contact between tip and stump.[14,29] There was no difference in survival between oblique and transverse fingertips, perhaps reflecting the small overall number of oblique amputations, and the lack of differentiation between volar/dorsal and lateral oblique amputations, which may differ in their survival potential.[29] This study also found no difference in survival between partial and complete amputation, contributing to the lack of consensus within the literature around the advantage of preserving all original attachments with the origin in an attempt to improve graft survival. The presence of a fracture or exposed bone also had no impact on graft survival.

The complication rate, regardless of graft take, is an important indicator of graft success and occurred for a number of reasons. Sixteen percentage of patients developed an infection of their composite graft, similar to the 17% reported by Butler et al.[8] Like Butler et al.,[8] grafts that became infected tended to fail. Infection was more likely in patients under 4 and where bone was exposed. Bone denuded of periosteum inhibits granulation tissue forma-

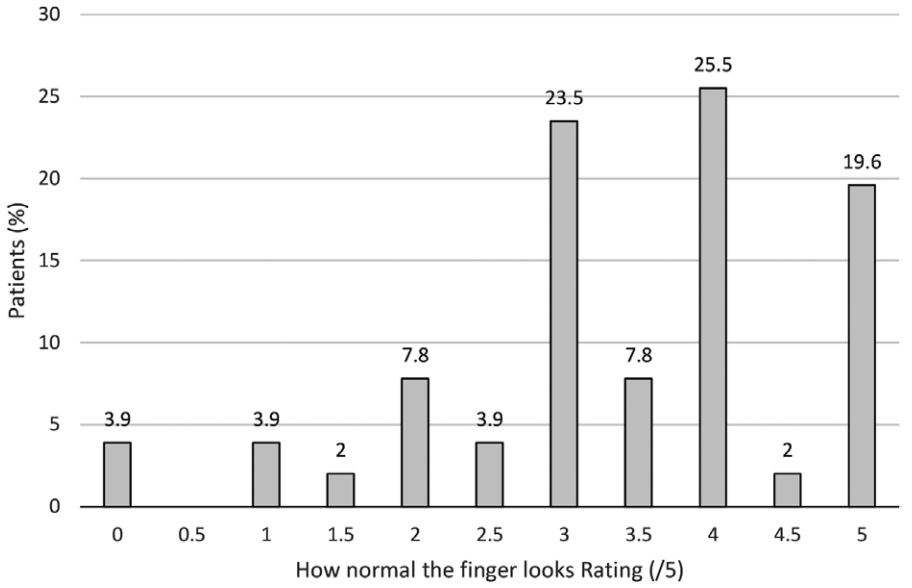

Fig. 6. Bar graph showing ratings of how normal the finger looks out of 5 (5 = completely normal, 0 = completely abnormal), shown as a % of the 51 patients who answered this question.

tion and prolongs wound healing,[30,31] which may contribute to infection risk. Graft infections were also anecdotally more likely in cases of postoperative trauma and failure to adhere to antibiotics, factors not directly measured. Our revision rate was 9%, similar to the 10% reported by Eberlin et al.[25] but higher than the 2% reported by Murphy et al.[7] Five revisions were to debride necrotic or infected tissue and 4 were for terminalization due to exposed bone, a complication of failed grafts, consistent with the finding that failed grafts were more likely to require a second operation. Most composite grafts were left to demarcate. If an exchar formed, then this was left to dry out until the necrotic piece of tissue came away, as long as there was no infection. Often the tissue left underneath had reepithelialized and required only minimal dressings thereafter, as the composite graft itself had acted like a biological dressing. Nine percentage of patients experienced wound healing complications, mostly overgranulation. Psychological complications were found in 4 patients, occurring either because of the trauma itself, or due to cosmetic concerns around the resulting deformity.

Interestingly, parents and patients had a positive attitude toward grafts and viewed graft survival as higher than that defined by the medical team. This perhaps re-

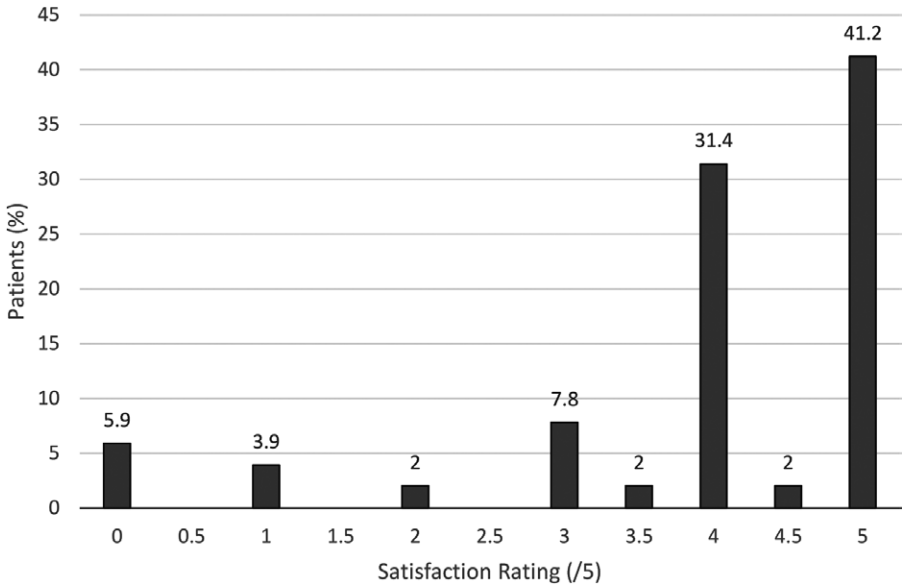

Fig. 7. Bar chart showing satisfaction scores out of 5 as a percentage of the 49 patients/parents who answered the question: "How satisfied are you with how the injured finger looks now? *please circle*: (not at all satisfied) 0 – 1 – 2 – 3 – 4 – 5 (completely satisfied)."

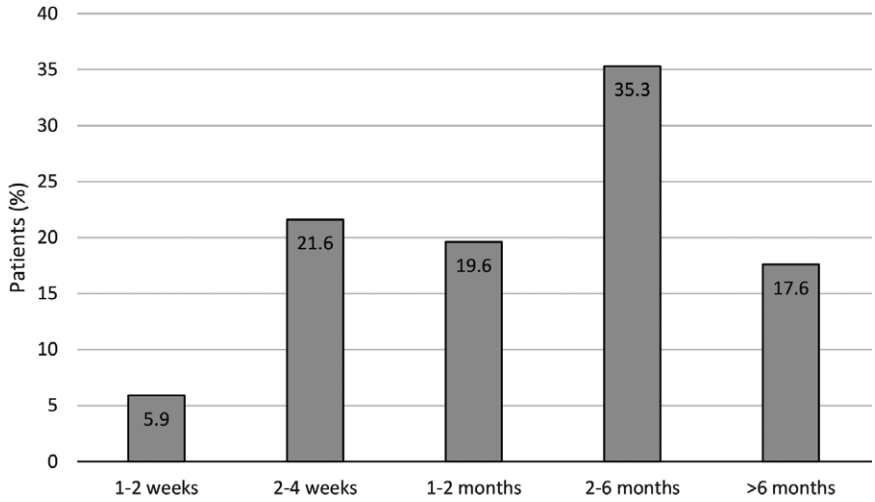

Fig. 8. Graph showing time before children were using their fingers in normal activities, shown as percentages out of the 51 patients/parents.

Table 11. Comparison of Graft Survival Rates in the Literature, in order of Increasing Graft Take

Study (y)	Patients (N)	Graft Survival (%)		
		Complete	Partial	Failure
Eberlin et al.[11]	39	7.7	59	33.3
Butler et al.[8]	97	10	34	56
This study	100	13	46	41
Murphy et al. (2016)[7]	96	16	52	32
Kiuchi et al.[11]	32	18.8	53.1	28.1
Moiemen et al. (1997)[5]	50	22	52	26
Mean		14.6	49.2	36.2

flects appropriate preoperative counseling to managing expectations, or suggests parents and patients considered grafts to survive if function, sensation and cosmesis were restored. Parents and patients who perceived the graft to fail tended to report more cosmetic disturbances and were less satisfied with the results. Satisfaction rating was higher than ratings of how normal the fingertips looked. Other authors report high patient satisfaction.[4,25] Cosmetic complications were present in more than half of patients. Nail deformities are common after composite grafting.[8] Finger shortening and nail curving may relate to the bone nibbling when bone was exposed.[32] Sensory complications occurred in under 30% of patients, with tenderness of the scar or graft the most likely complaint. It mostly took 2–6 months before the finger function was returned, consistent with the medical reported follow-up time of 4.5 months. A long healing time has been emphasized by previous authors.[18]

This study was mainly limited by its design as a retrospective case series, subject to the quality of medical notes and reporting bias. Sensory and functional outcomes are hard to assess in young patients, and parents found some questions difficult to answer. The nature of retrospectively relying on consistency in notes decreased the ability to assess factors such as antibiotic use and steps taken by the patient in the time between injury and surgery. Future work should use prospective designs to ensure improved methodology for measuring graft take, use consistent definitions and outcomes to enable synthesis of results, and should compare composite grafts to alternative treatment strategies.

CONCLUSIONS

The goal of treating fingertip amputations is to maintain cosmetic appearance and digital length, restore function, provide soft-tissue protection, all while avoiding complications and achieving high patient satisfaction. Composite grafts, despite not taking completely in most cases, were extremely successful in terms of these goals. Composite grafts mainly functioned as biological dressings, which facilitated healing. This case series uniquely highlights the possible psychological outcomes of composite grafts in the pediatric population, and our results suggest that patients should be counseled about the possibility of their occurrence. Composite grafts of patients younger than 4 and from nonavulsion injuries are more likely to survive. Composite grafts can be successful if sutured on up to 24 hours after injury if the tip has been appropriately cooled, but after 24 hours survival rates are poor. No difference in graft take between grafts replaced before or after the 6-hour "ischemic" time was seen. Given the low morbidity associated with grafts and high patient satisfaction composite grafting is a worthwhile procedure in distal fingertip amputations.

Aina Greig, MA, PhD, FRCS(Plast)
Guy's and St Thomas Hospital
London, SE1 7EH
E-mail: aina.greig@gstt.nhs.uk

REFERENCES

1. Fetter-Zarzeka A, Joseph MM. Hand and fingertip injuries in children. *Pediatr Emerg Care.* 2002;18:341–345.
2. Gellman H. Fingertip-nail bed injuries in children: current concepts and controversies of treatment. *J Craniofac Surg.* 2009;20:1033–1035.

3. Huang HF, Yeong EK. Surgical treatment of distal digit amputation: success in distal digit replantation is not dependent on venous anastomosis. *Plast Reconstr Surg.* 2015;135:174–178.
4. Chen SY, Wang CH, Fu JP, et al. Composite grafting for traumatic fingertip amputation in adults: technique reinforcement and experience in 31 digits. *J Trauma.* 2011;70:148–153.
5. Moiemen NS, Elliot D. Composite graft replacement of digital tips. 2. A study in children. *J Hand Surg Br.* 1997;22:346–352.
6. Heistein JB, Cook PA. Factors affecting composite graft survival in digital tip amputations. *Ann Plast Surg.* 2003;50:299–303.
7. Murphy AD, Keating CP, Penington A, et al. Paediatric fingertip composite grafts: do they all go black? *J Plast Reconstr Aesthet Surg.* 2017;70:173–177.
8. Butler DP, Murugesan L, Ruston J, et al. The outcomes of digital tip amputation replacement as a composite graft in a paediatric population. *J Hand Surg.* 2015: p. 1753193415613667.
9. Douglas B. Successful replacement of completely avulsed portions of fingers as composite grafts. *Plast Reconstr Surg Transplant Bull.* 1959;23:213–225.
10. Hirasé Y. Postoperative cooling enhances composite graft survival in nasal-alar and fingertip reconstruction. *Br J Plast Surg.* 1993;46:707–711.
11. Kiuchi T, Shimizu Y, Nagasao T, et al. Composite grafting for distal digital amputation with respect to injury type and amputation level. *J Plast Surg Hand Surg.* 2015;49:224–228.
12. Rose EH, Norris MS, Kowalski TA, et al. The "cap" technique: nonmicrosurgical reattachment of fingertip amputations. *J Hand Surg Am.* 1989;14:513–518.
13. Eo S, Hur G, Cho S, et al. Successful composite graft for fingertip amputations using ice-cooling and lipo-prostaglandin E1. *J Plast Reconstr Aesthet Surg.* 2009;62:764–770.
14. Dagregorio G, Saint-Cast Y. Composite graft replacement of digital tips in adults. *Orthopedics.* 2006;29:22–24.
15. Uysal A, Kankaya Y, Ullusoy MG, et al. An alternative technique for microsurgically unreplantable fingertip amputations. *Ann Plast Surg.* 2006;57:545–551.
16. Kusuhara H, Itani Y, Isogai N, et al. Randomized controlled trial of the application of topical b-FGF-impregnated gelatin microspheres to improve tissue survival in subzone II fingertip amputations. *J Hand Surg Eur Vol.* 2011;36:455–460.
17. Imaizumi A, Ishida K, Arashiro K, et al. Validity of exploration for suitable vessels for replantation in the distal fingertip amputation in early childhood: replantation or composite graft. *J Plast Surg Hand Surg.* 2013;47:258–262.
18. Son D, Han K, Chang DW. Extending the limits of fingertip composite grafting with moist-exposed dressing. *Int Wound J.* 2005;2:315–321.
19. Urso-Baiarda FG, Wallace CG, Baker R. Post-traumatic composite graft fingertip replantation in both adults and children. *Eur J Plast Surg.* 2009;32:229–233.
20. Eberlin KR, Zaleski KL, Snyder HD, et al.; Medical Missions for Children. Quality assurance guidelines for surgical outreach programs: a 20-year experience. *Cleft Palate Craniofac J.* 2008;45:246–255.
21. Weiland AJ, Villarreal-Rios A, Kleinert HE, et al. Replantation of digits and hands: analysis of surgical techniques and functional results in 71 patients with 86 replantations. *J Hand Surg Am.* 1977;2:1–12.
22. Morrison WA, O'Brien BM, MacLeod AM. Evaluation of digital replantation—a review of 100 cases. *Orthop Clin North Am.* 1977;8:295–308.
23. Agha RA, Fowler AJ, Rajmohan S, et al.; PROCESS Group. Preferred reporting of case series in surgery; the PROCESS guidelines. *Int J Surg.* 2016;36:319–323.
24. Biemer E. Definitions and classifications in replantation surgery. *Br J Plast Surg.* 1980;33:164–168.
25. Eberlin KR, Busa K, Bae DS, et al. Composite grafting for pediatric fingertip injuries. *Hand (N Y).* 2015;10:28–33.
26. Sears ED, Chung KC. Replantation of finger avulsion injuries: a systematic review of survival and functional outcomes. *J Hand Surg Am.* 2011;36:686–694.
27. Yu H, Wei L, Liang B, et al. Nonsurgical factors of digital replantation and survival rate: a metaanalysis. *Indian J Orthop.* 2015;49:265–271.
28. Dec W. A meta-analysis of success rates for digit replantation. *Tech Hand Up Extrem Surg.* 2006;10:124–129.
29. Park HC, Bahar-Moni AS, Cho SH, et al. Classification of distal fingertip amputation based on the arterial system for replantation. *J Hand Microsurg.* 2013;5:4–8.
30. Brown PW. The fate of exposed bone. *Am J Surg.* 1979;137:464–469.
31. Hurwitz DJ. Osseous interference of soft tissue healing. *Surg Clin North Am.* 1984;64:699–704.
32. Lee DH, Mignemi ME, Crosby SN. Fingertip injuries: an update on management. *J Am Acad Orthop Surg.* 2013;21:756–766.