INTRODUCTION

Fingertip amputations are common in children, often occurring after crush injuries in doors1,2 (Fig. 1). When there are no available vessels for anastomosis, a composite

**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 53% higher than medical-reported survival. Cosmetic issues were the most common 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.)
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.21 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’s24 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 classification5 (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

| Parameter                                | Description                  | Value |
|------------------------------------------|------------------------------|-------|
| No. patients (N)                        |                              | 100*  |
| No. fingertips (N)                      |                              | 100*  |
| Finger 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) |
| Sex N(%)                                |                              |       |
| Males: N = 57 (57%)                     |                              |       |
| Females: N = 43 (43%)                   |                              |       |
| Referral source, N (%)                  |                              |       |
| Direct: 27 (27%)                        |                              |       |
| Transfer: 73 (73%)                      |                              |       |
| Degree of amputation                    |                              |       |
| Crush: 75 (75%)                         |                              |       |
| Laceration: 13 (13%)                    |                              |       |
| Arulsion: 13 (13%).                     |                              |       |
| Fracture present                        |                              |       |
| Present: 29 (29%)                       |                              |       |
| Bone exposed                            |                              |       |
| Exposed: 60 (60%)                       |                              |       |
| Graft survival                          |                              |       |
| Complete: 13 (13%)                      |                              |       |
| Partial: 46 (46%)                       |                              |       |
| 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%)                            |                              |       |
| 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.
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 conducted7,8; 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 non-parametric. 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 fisher’s 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
Complete No areas of necrosis at follow-up
Partial Any graft for which there were patches of necrotic tissue interspersed with viable tissue

Table 2. Definitions of Graft Success

| Graft Status | Description |
|--------------|-------------|
| 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?

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).

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 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 fingertip operations on before 6 hours (though no repairs after 24 hours survived).

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 fingertip operations 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
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
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 \((N = 29, 56.9\%)\) by an average of \(3.93 \pm 2.84\) 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 \([14.6\% \text{ (range, 7.7–22\%) for complete survival and 49.2\% \text{ (range, 34–59\%)} for partial survival, respectively; Table 11}\). 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., 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

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

| Outcome Measure                        | Outcomes                  |
|----------------------------------------|---------------------------|
| Fingertip survival*                    | Yes: 40 (78.4\%)          |
| Sensory outcomes                       |                            |
| Sensation                              | Normal: 27 (52.9\%)       |
| Cold intolerance                       | Yes: 9 (17.6\%)           |
| Numbness                               | Yes: 8 (15.7\%)           |
| Tender tip/scar                        | Yes: 15 (29.4\%)          |
| Cosmetic outcomes                      |                            |
| Normal appearance rating               | Median: 3.5/5 (range, 0–5) |
| Finger shortening*                     | Yes: 29 (56.9\%)          |
| Normal nail growth                     | Yes: 26 (51.0\%)          |
| Abnormal curve of nail                 | Yes: 19 (37.3\%)          |
| Nail shortening                        | Yes: 47 (92.2\%)          |
| Absent nail                            | Yes: 3 (5.9\%)            |
| Satisfaction with appearance           | Median: 4/5 (range, 0–5)  |
| Functional outcomes                    |                            |
| Time before using hand/finger in normal activities | 1–2 wk: 5 (5.9\%)         |
| Felt fully informed                    | Yes definitely: 38 (74.5\%) |
| Who answered                           | Parent: 41 (80.4\%)       |

*All questions were answered by 51 patients except for “shortening” \((N = 50)\) and “satisfaction with appearance” \((N = 49)\).
The complication rate, regardless of graft take, is an important indicator of graft success and occurred for a number of reasons. Sixteen percent 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 peristium inhibits granulation tissue forma-
tion and prolongs wound healing,\textsuperscript{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.,\textsuperscript{25} but higher than the 2\% reported by Murphy et al.\textsuperscript{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-
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.

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