Composite grafts for fingertip amputations: a systematic review

Madeleine L. Landin, BSc (Hons)a, Mimi R. Borrelli, MBBS, MSb, Vikram Sinha, BSc (Hons)c, Riaz Agha, BSc (Hons), MBBS, MSc (Oxon), DPhil (Oxon), MRCSEng, FRSA, FHEA, FRSPHc, Aina V.H. Greig, MA, PhD, FRCS (Plast)d,*

Abstract
There is debate in the literature surrounding the management of fingertip amputations. The role of composite grafts lacks clarity in terms of outcomes and complications. Hence, there is a need for an evidence synthesis to guide practice. A search of the databases OVID MEDLINE, PubMed, EMBASE, SCOPUS, The Cochrane Library, and clinical trial registries was conducted, from 1946 to January 2020, using the key terms “fingertip,” “digital tip,” “digit,” “finger,” “thumb,” “amputation,” “replantation,” “reattachment,” “reimplantation,” and “composite graft.” Studies reporting primary data on the outcomes of composite grafts of 5 or more digits were included. The studies included in this systematic review ranged in year of publication from 1959 to 2019. Data extraction included demographic details, functional, esthetic and adverse outcomes. Twenty-three articles were included. Outcome data on composite grafts are heterogeneous and little standardization of measurements exists, making interpretation challenging. Identified factors associated with improved outcomes include lower age, distal amputation levels by cut mechanism and decreased time to operation. Smoking is associated with poorer composite graft outcomes. Although survival rates vary greatly, composite grafting may be useful in certain cases and provide good functional and sensation outcomes with good patient satisfaction.

Keywords: Composite graft, Distal fingertip, Amputation, Reconstruction

The fingertip is the segment distal to the insertion of the flexor and extensor tendons on the distal phalanx. A fingertip amputation is the loss of a part of a finger distal to the level of the distal interphalangeal joint (DIPJ). It is a common presentation to the emergency department. Crush injuries from doors are the most common cause of fingertip amputations in children. Treatment aims to restore a painless, minimally shortened digit with durable and sensate skin, preserved function, and a satisfactory esthetic outcome. Smoking is associated with poorer composite graft outcomes. Although survival rates vary greatly, composite grafting may be useful in certain cases and provide good functional and sensation outcomes with good patient satisfaction.

Composite grafting has been widely performed for distal fingertip amputations, but variable success rates are reported in the literature. Key complications include infection and necrosis. Consequently, many are hesitant to use composite grafts in adults. There is additional controversy as to which factors influence composite graft success; amputation-reattachment delay, amputation mechanism, and/or level. Although multiple previous case series document composite graft outcomes, there has been no formal synthesis of results. Therefore, a systematic review was conducted to understand the indications, functional and esthetic outcomes, complications, secondary surgery, and factors associated with the success of composite grafting for fingertip amputation. This review aims to help guide evidence-based practice.

Aims
The aim of this systematic review was to evaluate the available information in the literature about the survival of composite grafts in the treatment of distal fingertip amputations. The ultimate aim is to help guide evidence-based practice.

Methods
This systematic review was conducted in line with the Cochrane Handbook for Systematic Reviews and Interventions and is
compliant with PRISMA guidelines\cite{12}. A systematic review protocol was published\cite{11}, and the systematic review was registered a priori: https://www.researchregistry.com.

**Exclusion criteria**

Evidence-based Medicine\cite{13} were considered for inclusion if they counted a priori: https://www.researchregistry.com.

**Studies included**

Original research studies of levels 1–5 of the Oxford Centre for Evidence-based Medicine\cite{13} were considered for inclusion if they reported data concerning the relevant outcomes, as well as unpublished data, if methods and data were accessible. No duplicate articles nor articles not reporting primary data were included.

**Participants**

The patient population included children and adults receiving non-microsurgical replantation following distal fingertip amputations, with the aim of reviewing outcomes in these cases in order to elucidate the role of non-microsurgical replantation in the management of distal finger amputations.

**Intervention**

The interventions included were composite grafting of the distal tip via non-microsurgical methods following fingertip amputation. Any studies in which microsurgical reconstruction was used were not included. Articles were included if they reported on the survival outcomes of distal fingertip amputations treated with primary composite grafting of the amputated tip. All articles using subcutaneous pocket techniques, “pulp flaps” or microsurgical replantation were excluded, as were articles reporting on data of <5 cases, following previous research\cite{9}.

**Outcomes**

The primary outcome measured was graft survival. Secondary outcomes are detailed below.

**Search methods and search terms**

An electronic database search was conducted on OVID Medline, PubMed, EMBASE, SCOPUS, The Cochrane Library and clinical trial registries using the terms “fingertip” “fingertips” “digital tip” “digital tips” “digit” “digits” “finger” “fingers” “thumb” “thumbs” “amputation” “amputations” “injury” “injuries” “replantation” “replantations” “reattachment” “reattachments” “reimplantation” “reimplantations” “composite graft” ““composite grafts” as keywords combined with the Boolean logical operators “OR” and “AND”. The search was limited to English studies and studies conducted in humans. Duplicated studies were removed.

**Identification and selection of studies**

Two independent reviewers (M.R.B. and M.L.L.) screened the title and abstract of each of the published articles for inclusion according to the criteria listed in Tables 1–2. Full-length manuscripts were reviewed for articles which met the inclusion criteria, if no abstract was published or if the abstract did not have sufficient information to determine eligibility.

**Quality scoring**

The Grading of Recommendation Assessment, Development and Evaluation (GRADE) system was used to assess the methodological quality of included studies.

**Analysis**

Characteristics of included studies are presented as counts and percentages. Continuous data are expressed as means or median values where stated. Meta-analysis was not performed as only one study reported comparative data on outcomes of composite grafting compared to other methods of managing distal fingertip amputations.

**Results**

The search yielded a total of 5790 articles, after 2061 duplicates were removed, 3729 underwent title and abstract screening (stage 1), and 119 articles underwent full-text screening (stage 2). A total of 23 articles met the full inclusion criteria \cite{10,14–35}.

**Article demographics**

The articles included covered data collection from 1959 to 2019 (Table 3). The majority of the work published on composite grafting outcomes was conducted in Japan (n = 5), followed by the United Kingdom (n = 4) and the USA (n = 3), Korea (n = 3), Italy (n = 3), Australia (n = 1), Taiwan (n = 1), Turkey (n = 1) and France (n = 1). The highest level of evidence of our included studies was 4, corresponding to a randomized controlled trial (RCT) by Kusuhara et al\cite{29}. In terms of article quality, every study had a GRADE score of “very low”, with the exception of the aforementioned RCT conducted by Kusuhara et al\cite{29} which was graded as “moderate”.

### Table 1

| Inclusion criteria | Exclusion criteria |
|-------------------|-------------------|
| Primary data      | Composite graft pocketing |
| Outcomes of “composite grafts” or “non-microsurgical replantation” of the amputated part | Microsurgical vascular anastomosis |
| Graft survival    | Use of additional skin flaps or pulp flaps |
| Report on ≥ 5 cases | Incomplete data |
| Articles written in English | Cases of composite graft as a secondary revision |

### Table 2

| Secondary outcomes. |
|---------------------|
| Follow-up period    |
| Reported adverse outcomes, including revision surgery |
| Findings of any additional factors associated with graft survival (eg, age, smoking, diabetes) |
| Sensory outcomes    |
| Functional outcomes |
| Esthetic outcomes   |

\[\text{Table 2}\]
Patient demographics

In total, the number of reported patients included across all studies was 810, with 264 females (Table 4). In addition, Urso-Baiarda et al[35] reported on 108 digits and Imaizumi et al[26] on 18 digits, with the number of patients not specified. The mean age of participants per study ranged from 2.4[32] to 43.2 years[28] (range 0–74)[28,32] and each article reported on anywhere from 7 to 108 digits, with a mean of 41.5 digits[33,35]. The majority of included studies reported on outcomes of a single digit composite grafting per study participant, with five articles reporting outcomes of more than one digit per patient[17,22,24,34].

Amputation details

Of the included studies, 18[10,14–22,25,26,28,30–34] reported the mechanisms of amputation and the remaining 5[23,24,27,29,35] did not (Table 4). Most amputations followed crush injuries. In 2 studies (Rose et al[33] and Douglas[19]), injury details were only included for a few patients. Of note, there was significant heterogeneity in the description of amputation level, making it difficult to compare results; across the 23 studies included, 6 different amputation classification systems were used. Four articles did not include a classification system[19,20,23,33].

Factors affecting graft take

Twelve studies looked specifically at factors predictive of graft failure[15,16,20–22,27–29,31,32,34,35] (Table 4). In the study by Eo et al[21], crush injury was independently associated with graft failure, whereas distal cutting amputations grafted within <5 hours from injury were associated with good results in bivariate analysis. Time to operation was found to be a statistically significant factor in graft survival by Moiemen and Elliot[31], however, 4 studies showed no statistically significant effect of time to operation[15,16,20,32]. In adult patients, comorbid and smoking status are factors likely important in predicting graft take, however, they were frequently underreported in all the 17 studies reporting outcomes in adults[10,14,17–23,27,28,30,33–35].

The Ishikawa[18,28,29,35,36] and modified Ishikawa[15,16,31,32,36] were the most commonly used systems, but the Allen[17,25,26,37], Hirase[14,24,27,30], and Das and Brown[10,21,38] classifications were used by at least 2 of the studies reviewed. Two articles used their own classification systems[22,34] that were not endorsed by articles published after these manuscripts. While all the classification systems base categories on different anatomical landmarks, more distal amputations predominated.
Smoking and comorbidity status were only reported in 7 of all the 23 articles reviewed [10,15,19,21,22,27,30,33]. However, when analyzed as a factor, smoking status significantly decreased the chance of fingertip graft survival; Heinstein et al. [22] reported that in adult patients, smoking was the only significant factor independently associated with graft loss. Kankaya et al. [27] also reported that 3 of the 6 composite graft failures (partial or total graft loss) were in smokers. The RCT by Kusuhara et al. [29] found no statistically significant increase in survival from the application of topical basic fibroblast growth factor (b-FGF).

**Surgical technique**

Surgical technique and reporting on specific operative details varied (Table 5). Classic composite grafting (ie, no modifications) was the most commonly used method, with 19 of the included articles adopting this technique [10,14–16,18–26,28–32,34]. The cap technique, whereby the proximal stump is de-epithelialized and the amputated part modified so as to allow for maximal contact between the stump and amputated part, was adopted in three studies [17,27,31]. Fingertip amputations (ie, distal to the DIPJ) almost always involve the nailbed, however, only 11 of the 23 studies specifically describe repair of the nail bed [14–16,19,22,25,27,31]. and Murphy et al. [32] describe removal. Part of the management (and “preservation”) of the nailbed involves management of the nail; the nail may be removed and sutured back onto the nailbed to act as a splint to guide new nail growth or discarded due to contamination. When discarded, other material (most commonly foil) can be used as a splint, or surgeons may not use a splint at all. Three of the 12 articles mentioning nailbed management describe removing and resutting the nail bed [22,26,31]. Daggregorio and Saint-Cas [10] and Chen et al. [17] stated that the nail bed was preserved. Proximal part trimming was only reported in 3 articles, that is those using the cap technique [17,27,31].

Heinstein and Cook [22] were the only authors to explicitly state that proximal part trimming had not been performed. Defatting of the amputated part was performed in 5 studies [15–18,27]. Removal of small fragments of bone was performed in three studies [16,20,32] and in 5 cases [15,17,27,28,31] bone removal or trimming were reported. Prostaglandin E-1 (PGE-1) was the most commonly used pharmacological adjunct and was reported in 5 articles [10,21,23,24,28]. Tetanus antitoxin/prophylaxis was administered in 2 articles [19,27]; Kusuhara et al. [29] reported using b-FGF. Cooling (either preoperatively or postoperatively) was reported in 12 articles [10,14,16,19,21–23,25,27,31,32]. Splinting was reported in 10 studies [15–17,20,22,31–34] and antibiotics were used in 14 [10,14–16,20–22,27,28–30,34].

**Graft survival**

The primary outcome variable was graft survival. Graft survival rates, however, varied significantly between studies, and importantly, so did the definition of graft survival (Tables 5–9). The lowest reported complete graft take was 7.7% [20] the highest graft take was 93.5% [17,19]. Ten articles stratified graft survival into complete, partial or no survival [10,14,19,22,25–30,33,33], however, 3 articles binary-ized [21,26,34] graft survival into “success” or “failure,” and 7 articles reported healing in terms of graft take [16–18,20,27,31,32]. Furthermore, the definitions of graft success and failure were not standardized, with few articles citing previous work to ensure consistency (Fig. 2).

**Adverse outcomes**

Adverse outcomes were reported by 17 of the 23 studies [10,15–24,26–28,30,32,33] (Table 6). Adverse outcomes were inconsistently reported on and in varying degrees of detail. Necrosis was the most commonly reported adverse outcome, with 9 studies reporting this [17,20,21,23,24,27,30,33,33] and rates ranging from 2.08% [32] to 60.9% [27]. Infections were reported in 5 articles [15,16,19,27,32] and rates ranged from 1% [32] to 17% [15]. The most commonly included category of adverse outcome was reoperation, with rates ranging from 0% [33] to 56.3% [21]. The total complication rate was 15.6% [10,15–24,26–28,30,32,33] (Fig. 3).

**Cosmetic outcomes**

Eleven articles reported cosmetic outcomes [10,14–16,19,25,27,30,33] and antibiotics were used pharmacological adjunct and was reported in 5 articles [10,14,19,22,25,27,30,33]. The lowest reported complete graft take was 7.7% [20] the highest graft take was 93.5% [17,19]. Ten articles stratified graft survival into complete, partial or no survival [10,14,19,22,25–30,33,33], however, 3 articles binary-ized [21,26,34] graft survival into “success” or “failure,” and 7 articles reported healing in terms of graft take [16–18,20,27,31,32]. Furthermore, the definitions of graft success and failure were not standardized, with few articles citing previous work to ensure consistency (Fig. 2).

Eleven articles reported cosmetic outcomes [10,14–16,19,25,27,30,33] and antibiotics were used pharmacological adjunct and was reported in 5 articles [10,14,19,22,25,27,30,33]. The questionnaire formats used were heterogeneous. The questionnaire responses indicate that poor cosmetic outcomes are common, specifically with regards to nail deformity and shortening [15,16,31]. However, the results by Borrelli et al. [32] indicate that patients reported normal digit appearance at a median score of 3.5/5 on a Likert scale (Fig. 4).

**Sensory outcomes**

Eleven of the 23 articles reported specifically on sensory outcomes following composite grafting [10,14–17,19,25,27,30,33] (Table 8). Of these studies, objective method of 2-point discrimination was adopted in 7 articles [10,14,17,25,27,30,33]. The measurements were conducted between 6 months [17,27] and 2 years [14] postoperatively. The mean 2-point discrimination post composite grafting was 6.5 mm, which is only slightly greater than normal range for certain
| References                  | No. Patients | Mean Age & Range (y) | No. Females | No. Digits | Smoking or Comorbidity Status | Mechanism of Injury                      | Amputation Classification System | Amputation Level | Follow-up (mo) |
|-----------------------------|--------------|----------------------|-------------|------------|-------------------------------|-----------------------------------------|-----------------------------------|-----------------|----------------|
| Douglas[19]                 | 17           | —                    | —           | 17         | —                             | —                                       | Causative injury described in 7    | —               | —              |
| Rose et al[33]              | 7            | —                    | —           | 7          | —                             | —                                       | Described in 3                    | —               | All through lanula Range 6–72 mo |
| Hirase[23]                  | 32           | —                    | —           | 32         | —                             | —                                       | —                                 | Hirase          | —              |
| Hirase[24]                  | 10           | —                    | —           | 11         | —                             | —                                       | —                                 | —               | 1 y            |
| Moiemen and Elliot[31]      | 50           | 5.7 (1–14)           | 12          | 50         | —                             | Crush (door): 38                        | Modified Ishikawa                 | —               | —              |
| Adani et al[14]             | 7            | 24 (4–60)            | 1           | 7          | —                             | Crush (door): 3                         | Hirase                            | —               | 2 y total       |
| Heistein and Cook[25]       | 53           | 28 (1–71)            | 19          | 57         | Smokers: 12                    | Crush: 19                               | —                                 | —               | All had 12 wk follow up |
| Son et al[34]               | 56           | 28 (1–60)            | 13          | 60         | Alcohol: 23                    | Crush: 19                              | Other                             | DP1: 36         | —              |
| Kankaya et al[27]           | 23           | 32.41 (1.5–57)       | 4           | 23         | Diabetes: 8                    | Crush (transverse): 3                   | Ishikawa                          | Level 1: 8      | All checked 9–12 mo |
| Dagregorio and Saint-Cast[18]| 19           | 39.7 (25–58)         | 7           | 19         | Hypertension: 1                | Crush (transverse): 3                   | Ishikawa                          | Level II: 7     | —              |
| Unso-Balarda et al[35]      | —            | Median: 5.9          | —           | 108        | No diabetes*                   | —                                       | —                                 | —               | Mean healing time Children: 68 d Adults: 82 d |
| Eo et al[15]                | 24           | 31.2 (1–67)          | 13          | 24         | Smoking: 21% adults Steroid use: 2% children, 5% adults | Crush: 15 Cut: 9 | Das & Brown Type 1: 13 Type 2: 10 Type 3: 14 Type 3: 22 Type 4: 23 All subzone 2 | Distal: 3 2.63 All checked at 3 wk | —              |
| Chen et al[17]              | 27           | 40.5 (20–65)         | 5           | 31         | No diabetes or atherosclerosis | Crush: 21 Cut: 10 | — | — |
| Kusuhara et al[29]          | —            | —                    | —           | 18         | —                             | —                                       | —                                 | —               | —              |
| Imazumi et al[28]           | 10           | Distal: 4.8          | Middle: 3   | 10         | All amputation of finger pulp  | —                                       | —                                 | —               | —              |

Notes:  
*No diabetes*
| References       | No. Patients | Mean Age & Range (y) | No. Females | No. Digits | Smoking or Comorbidity Status | Mechanism of Injury                        | Amputation Classification System | Amputation Level | Follow-up (mo) |
|------------------|--------------|----------------------|-------------|------------|-------------------------------|------------------------------------------|-----------------------------------|-----------------|----------------|
| Butler et al[16] | 97           | 4.3 (1–15)           | 42          | 97         | —                             | Crush: 94                                | Moelmen’s modification of Ishikawa’s classification | Level 1a: 12   | 1.8 mean       |
| Eberlin et al[20]| 39           | 5.3 (1–22)           | 15          | 39         | —                             | Crush (door): 24 Mechanical device: 6 Crush (other): 5 Laceration: 2 Sport: 1 Strangulation: 1 | —                             | All distal to finger DIPJ/thumb IPJ | 4.5 mean       |
| Kiuchi et al[28] | 27           | 43.2 (1–74)          | 5           | 32         | —                             | Crush avulsion: 16 Clean cut: 6 Blunt Cut: 10 | Ishikawa                        | Subzone 1: 4    | 2.8            |
| Idone et al[25]  | 8            | 34.3 (24–45)         | 1           | 8          | —                             | Sliding door: 3 Crush: 2 Saw: 2 Knife: 1 | Allen                           | Level 1: 2      | 10             |
| Murphy et al[25] | 96           | Median: 2.4 (0–16)   | 57          | 96         | —                             | Crush: 89 Laceration: 4 Not recorded: 3 | Moelmen’s modification of Ishikawa’s classification | *Level 1a: 16   | 2.23           |
| Eo et al[21]     | 94           | 39 (1–68)            | 25          | 94         | Smoker: 34                    | Non smoker: 60                           | Das & Brown                       | Type 1: 44      | Mean 3         |
| Borrelli et al[35] | 100         | 4.41 (0.08–15.83)    | 43          | 100        | Sickle cell disease: 1 HIV: 1 NAI: 1 | Crush: 75 Avulsion: 13 Laceration: 12 | Modified Ishikawa                  | Level 1a: 3     | 4.65           |
| Losco et al[30]  | 14           | 40 (24–52)           | 2           | 14         | Smokers excluded              | Peripheral vascular disease 2            | All sharp Hirase                   | All 2a or 2b    | 12             |

*D as documented in original article.  
DIPJ indicates distal interphalangeal joint; HIV, Human Immunodeficiency Virus; IPJ, interphalangeal joint; NAI, nonaccidental injury.
| References        | Composite Grafting Technique | Mean Time to Surgery (h) | Nail Bed Preservation | Proximal Part Trimming | Amputated Part Defatting | Bone Removal/Trimming | Bony Fixation | Pharmacological Adjuncts | Cooling Used | Splint | Antibiotics Used | Outcomes (Graft Survival) % |
|-------------------|------------------------------|--------------------------|-----------------------|------------------------|--------------------------|------------------------|---------------|--------------------------|--------------|--------|--------------------|-----------------------------|
| Douglas[19]       | Classic                      | —                        | —                     | —                      | —                        | —                      | Variable suture | Variable tetanus antitoxin | Variable     | Variable | —                  | CS: 88.2, PS: 11.8          |
| Rose et al[33]    | Cap                          | —                        | —                     | Yes                    | —                        | —                      | Yes           | No                       | —            | —      | —                  | CS: 71, PS: 29              |
| Hirase[23]        | Classic                      | —                        | —                     | —                      | —                        | —                      | —             | —                        | PGE 1        | Variable | —                  | No cooling: S: 23.8, Cooling: S: 81.8, S: 90.9 |
| Hirase[24]        | Classic                      | —                        | —                     | —                      | —                        | —                      | —             | —                        | PGE 1        | Variable | —                  | No cooling: S: 23.8, Cooling: S: 81.8, S: 90.9 |
| Moiemen and Elliot[21] | Classic                  | Complete: 3.9 Partial: 7 Failed: 7.8 | —                     | —                      | —                        | —                      | —             | —                        | —            | —      | —                  | No cooling: S: 23.8, Cooling: S: 81.8, S: 90.9 |
| Adani et al[14]  | Classic                      | Sutured                  | —                     | —                      | —                        | —                      | Variable longitudinal Kirschner | No           | Yes     | —                  | CT: 57.1, PS: 14.3          |
| Heisten and Cook[22] | Classic                  | —                        | —                     | —                      | —                        | —                      | Variable Kirschner wire | No           | —      | Variable preoperative | Yes            |
| Son et al[34]    | Classic                      | —                        | —                     | —                      | —                        | —                      | Yes           | —                       | Yes         | Yes     | CT: 73.9, PT: 17.4, F: 8.7 |
| kankaya et al[27] | Cap                         | —                        | —                     | —                      | —                        | —                      | —             | Tetanus prophylaxis         | Variable     | Yes     | —                  | CT: 91.7, Tissue survival: 100%, <75%: 33.3, 50-75%: 11.1, <50%: 27.8, Distal: 33.3, Middle: 57, Success: 33.3 |
| Dagregorio and Saint-Cast[18] | Classic            | All <4 h Nail bed sutured 7-0 | —                     | Variable               | —                        | Variable needle         | No            | —                       | Yes         | —      | —                  | Success: 52.6, PT: 15.7, F: 31.6, CS/PS: Adults: 86%, Children: 89.5 |
| Urso-Baiarda et al[25] | Classic                  | Median 6.5                | —                     | —                      | —                        | —                      | —             | —                        | —            | —      | —                  | CS: 91.7, Tissue survival: 100%, >75%: 33.3, 50-75%: 11.1, <50%: 27.8, Distal: 33.3, Middle: 57, Success: 33.3 |
| Eo et al[20]     | Classic                      | 5                        | —                     | —                      | —                        | —                      | Lipo PGE 1       | Yes                      | Wash & ointment | No     | —                  | CT: 93.5, Tissue survival: 100%, <75%: 33.3, 50-75%: 11.1, <50%: 27.8, Distal: 33.3, Middle: 57, Success: 33.3 |
| Chen et al[27]   | Cap                         | —                        | Yes                   | —                      | Variable                | —                      | —             | b-FGF                     | Yes          | —      | —                  | CT: 10, PT: 34, NT: 56, CT: 7.7, PT: 59, NT: 33.5 |
| Kusuhara et al[29] | Classic                   | —                        | —                     | —                      | —                        | —                      | —             | —                        | —            | —      | —                  | CT: 10, PT: 34, NT: 56, CT: 7.7, PT: 59, NT: 33.5 |
| Imai et al[26]   | Classic                     | Nail removed and nail bed sutured* | —                     | —                      | —                        | —                      | Variable Kirschner wire* | —            | —      | —                  | CT: 10, PT: 34, NT: 56, CT: 7.7, PT: 59, NT: 33.5 |
| Butler et al[15] | Classic                    | Complete: 6.5 Partial: 7.2 Nil: 6.7 | —                     | Variable               | —                        | Variable                | Small fragments | No                       | Preoperative | —      | Yes                 | CT: 10, PT: 34, NT: 56, CT: 7.7, PT: 59, NT: 33.5 |
| Eberlin et al[20] | Classic                    | If necessary             | —                     | No                     | Small fragments          | —                      | —             | —                        | Yes          | —      | —                  | CT: 10, PT: 34, NT: 56, CT: 7.7, PT: 59, NT: 33.5 |
individuals (manual laborers). However, in normal individuals the average range is between 2 and 3 mm [10,17,27,30,33,39]. The mean 2-point discrimination score excludes the results from Idone et al [25] and Adani et al [14], as these studies reported only ranges. Losco et al [30] were alone in using the Pain Visual Analogue Scale as another objective measure of sensation outcomes and the mean score indicated very mild pain [30,40]. Questionnaires were used in 5 studies [15–17,27,31]; however, the questions and format styles varied greatly. The questionnaire responses show favorable sensation outcomes in the majority of patients, however, symptoms such as cold intolerance are commonly reported, and range from 0% [19] to 65% [17] (numbness). Douglas et al [19] were the only authors to report sensation outcomes based on clinical observation (Fig. 5).

**Functional outcomes**

In total, ten studies reported on the functional outcomes following composite grafting [14–19,25,27,30,31] (Table 9). Losco et al [30] were the only authors to use objective measure, and graded functional recovery using the Q-DASH score and measured movement at the IPJ. The results of this indicates minimal disability [30,41,42] but with lessened motion at the IPJ [43]. The other studies recorded functional outcomes with questionnaires, however, each study used a unique questionnaire with different questions [15–17,30,31]. Results based on clinician reports showed that all patients used their hands normally or that all digits were functional [14,18,25,27] with the exception of Douglas [19], who only reported on functional outcomes of 2 patients. Of the 4 articles that reported on patient satisfaction with the results, the responses were favorable and showed that the majority of patients were pleased with the end result [15,17,27,30].

**Discussion**

Composite grafting is a simple technique for restoring the amputated fingertip in cases where microvascular replantation is not possible. This technique has most frequently been used to repair pediatric fingertip amputations due to the small caliber of affected vessels and the relative regenerative capacity of juvenile tissues [7]. To date, there has been no formal synthesis of results across individual studies. Therefore, we conducted the first systematic review of composite grafting for distal fingertip amputations to investigate whether it is a viable and worthwhile technique and what factors are most predictive of graft survival.

A total of 23 individual studies were reviewed in this systematic review. Across all studies, the success rates of composite grafting were highly variable, ranging from 7.7% [20] to 93.5% [17]. Adverse outcomes were common with infection rates as high as 17% [15] and reoperation rates of up to 56.3% [23]. The functional and sensory outcomes were favorable with high patient satisfaction. However, cosmetic outcomes were not optimal as detailed from the questionnaire responses and clinical reports, which show that finger shortening, and nail deformities are common. However, and importantly, the evidence available to date was of poor quality. Indeed, only one study was at the level 1a (the highest level) according to the Oxford criteria. This study by Kusuhara et al [29]; however, this study did not compare composite grafting to alternative methods for managing fingertip amputations not suitable for replantation (ie, stump management by primary closure), but rather compared success of grafting with and without application of b-FGF. In fact, no comparative studies looked at outcomes of composite grafts versus not grafting, and the majority of published articles were retrospective case series.
Another factor limiting study was the low participant number. A minority of available studies included >50 patients\textsuperscript{[10,14,15,17,21,22,25-28,30-32,35]}. A major outcome of this systematic review was to investigate factors predictive of graft survival. Smoking status and comorbidities are relevant when using composite grafting on adult patients. Of the 17 studies reporting results with adults, only 7 studies reported on smoking or comorbidity status\textsuperscript{[10,15,21,22,27,30,35]}. The studies that did report on smoking found, not surprisingly, that smoking was associated with poorer outcomes. A multivariable analysis\textsuperscript{[22]} found that smoking was an independent factor associated with poorer graft healing. Better graft survival has been linked to decreased time to operation\textsuperscript{[31]}, lower age\textsuperscript{[15,16]}, clean-cut injuries\textsuperscript{[21,28]}, and more distal amputation levels\textsuperscript{[16,28]}. These findings, in addition to future research, should help clinicians in stratifying patients to being at high risk of poor outcomes from composite grafting. A variety of operative techniques were described, including classic composite grafting and the cap technique. The cap technique has been shown to aid healing through providing increased contact surface between the stump and amputated part. However, the main limitation of this technique is the resulting finger shortening, which, depending on patient and injury factors, may be significant.

A secondary outcome investigated was predictors of poor postoperative outcomes. Adverse events following composite grafting are listed in Table 6.

### Table 6: Adverse Outcomes

| References                  | Adverse Outcomes                                                                 | Revision Operation (%) | Other Details                                      |
|-----------------------------|----------------------------------------------------------------------------------|------------------------|-----------------------------------------------------|
| Douglas\textsuperscript{[19]} | 1 infection<br>1 ulcer                                                          | 11.8                   |                                                     |
| Rose et al\textsuperscript{[38]} | 2 digits small areas necrosis<br>Cooling<br>1 necrosis<br>1 partial necrosis<br>Non-cooling | 0                      | Superficial eschar developed in several cases       |
| Hirase\textsuperscript{[23]} | 1 partial necrosis                                                                | 56.3                   | Cooling: 1 debridement                              |
| Adani et al\textsuperscript{[14]} | No infections or serious complications                                            | —                      | 1 finger pulp reverse vascular pedicle digital island flap reconstruction |
| Son et al\textsuperscript{[34]} |                                                                                   | —                      | Noncooling: 16 skin grafts/flaps                     |
| Kankaya et al\textsuperscript{[27]} | Superficial necrosis seen in 14 1 infection                                       | 8.7                    | 1 skin graft: 1 stump management by primary closure | debridements were performed on an outpatient basis |
| Daggregorio and Saint-Cas\textsuperscript{[18]} | 2 cases of partial take healed by secondary intention                           | 5.3                    | 1 cross finger flap adjunct                          |
| Urso-Baiarda et al\textsuperscript{[35]} |                                                                                   | —                      |                                                     |
| Eo et al\textsuperscript{[10]} | Scab formation was inevitable happened in 11 of 24                              | 8.3                    | 1 revision flap (cross finger)                      |
| Chen et al\textsuperscript{[17]} | 2 graft necroses                                                                  | 6.5                    | 1 tenner flap: 1 volar V-Y advancement flap          |
| Kusuhara et al\textsuperscript{[29]} | No significant complications                                                      | —                      | 1 volar V-Y advancement flap                         |
| Inaizumi et al\textsuperscript{[26]} | 11 post-operative infection                                                      | —                      | No blood transfusions                               |
| Butler et al\textsuperscript{[16]} |                                                                                   | —                      |                                                     |
| Eberlin et al\textsuperscript{[20]} | Indications for revision: patient/family dissatisfaction, persistent pain, or aesthetic deformity | 10                     | 2 operative debridement of nonviable tissue         |
| Kluchi et al\textsuperscript{[26]} | “There were no complications that affected graft survival”                       | —                      | 1 debridement and revision amputation               |
| Idone et al\textsuperscript{[20]} |                                                                                   | —                      | 1 debridement and V-Y advancement flap closure      |
| Murphy et al\textsuperscript{[32]} | 1 infected necrotic graft<br>1 necrotic graft                                      | 2                      |                                                     |
| Eo et al\textsuperscript{[21]} |                                                                                   | 10.6                   | 5 stump revisions & no reconstruction               |
| Borrelli et al\textsuperscript{[15]} | 17 infections<br>9 wound healing complications<br>4 psychological complications<br>1 hypersensitivity and phantom pain | 9                      | 3 tenner flaps: 2 distal abdominal flaps            |
| Losco et al\textsuperscript{[30]} | Minimal necrosis (<1 cm²) in 6                                                   | 0                      | 4 terminalisations of exposed bone                  |
| Landin et al. International Journal of Surgery Short Reports (2021) 6:e17 www.ijssr.com | | | |
### Table 7
Cosmetic outcomes.

| References          | Measurement Method | Questionnaire Results | Digit Shortening (Average, mm) | Nail Bed/Plate Growth & Nail Deformity | Other Details |
|---------------------|--------------------|-----------------------|---------------------------------|----------------------------------------|---------------|
| Douglas[19]         | Clinician reported | —                     | —                              | 1st case report: growth of the nail appeared normal | Case 3: slight thinning of the pad, but finger was normal |
| Rose et al[33]      | Objective          | Short digit: 28 (74%)  | 6                              | Flat nail growth returned in all digits | Pulp pinch averaged 67% Response rate: 76% |
| Moximen and Elliot[31] | Parental Questionnaire | Hooked nail: 22 (58%) | —                              | —                                      |               |
| Adani et al[14]     | Clinician reported | —                     | —                              | Nail deformity was observed in one finger | —             |
| Kankaya et al[27]   | Objective & clinician reported | —                     | 6.8                            | 5 patients had nail deformity | —             |
| Eo et al[30]        | Objective          | Abnormal appearance: 28 (67%) | —                              | *acceptable appearance* | —             |
| Butler et al[14]    | Parental questionnaire | Pulp abnormal: 17 (40%) | —                              | Nail absent: 1 (2%) Nail short: 10 (24%) | —             |
| Idone et al[25]     | Objective          | —                     | —                              | Partial nail deformity observed in 3 Remaining 5 normal nail growth & good cosmetic result at lamina | —             |
| Murphy et al[22]    | Clinician reported | —                     | —                              | 3 hook nail deformity | —             |
| Borrelli et al[5]   | Questionnaire       | Finger shortening: 29 (56.9%) | 3.93                           | 1 hook nail | —             |
| Adani et al[14]     | Clinician report & 2PD | < 7 in all patients | 2 y                            | Zone 1 (n = 2): Pain and cold intolerance were ameliorated after 2 mo Zone 2 (n = 15): Patient satisfaction on pain, sensibility, cold intolerance was achieved Zone 3 (n = 6): Patients had neither pain nor cold intolerance by the third postoperative month | —             |
| Kankaya et al[27]   | Questionnaire & 2PD | 7.26                  | 6 mo                           | Zone 1 (n = 2): Pain and cold intolerance were ameliorated after 2 mo Zone 2 (n = 15): Patient satisfaction on pain, sensibility, cold intolerance was achieved Zone 3 (n = 6): Patients had neither pain nor cold intolerance by the third postoperative month | —             |
| Eo et al[33]        | 2PD                | 5.5                   | —                              | Some complained of persistent paraesthesia | —             |
| Chen et al[37]      | Questionnaire & 2PD | 6.3                   | 6 mo                           | Scar tender: 3 (7%) Cold intolerance: 7 (17%) Hypersensitive: 3 (7%) | —             |
| Butler et al[14]    | Parental Questionnaire | —                     | —                              | Reduced: 14 (27.5%) Increased: 10 (19.6%) Normal: 27 (52.9%) Cold intolerance: 9 (17.6%) Numbness: 8 (15.7%) | —             |
| Idone et al[25]     | 2PD                | < 5 in all            | —                              | No patient complained of dysesthesia or cold intolerance | —             |
| Borrelli et al[14]  | Questionnaire      | —                     | —                              | — | —             |
| Losco et al[30]     | 2PD & Pain Visual Analogue Scale (VAS) | 7.1 (range: 6–9) | 12 mo                          | Mean VAS score 1.3 | —             |

2PD indicates 2-point discrimination, VAS, visual analogue scale.
Grafting were inconsistently reported among the included studies and only 17 articles reported adverse events\[^{10,15-24,26-28,30,32,33}\]. The overall complication rate was 15.6%. The recovery of composite grafts from the data indicate that adverse effects such as infection and necrosis are common and that reoperation mostly consists of debridement or the use of additional skin graft or flap procedures\[^{10,15-21,23,24,27,30,32,33}\].

One striking finding of this review is the huge variety in the small number of published studies. Interestingly, in the 23 of studies, 6 different classification schemes were used to describe the level of amputations. One of the more commonly used, the Ishikawa classification adapted to distal fingertip amputations, categorizes amputations in terms of zones of the fingertip based on the nail. It comprises four zones distal to the DIPJ and takes into account the angle of the amputation\[^{36}\]. The Hirase classification\[^{23,24}\] is based on the course of the digital artery, whereas the Allen classification includes reference to bony fragments in the amputated stump and advice for management based on the level\[^{37}\]. Moreover, descriptions of the types of injuries sustained were not reported in a standardized fashion and five articles did not classify the mechanism of injury\[^{23,24,27,29,35}\]. Finally, the definition of graft survival, the main outcome investigated, also significantly varied between studies. One of the main limitations in the data is the reporting of the composite graft healing. Success or failure or graft take is defined differently.

### Table 9

**Functional outcomes and patient satisfaction.**

| References        | Measurement Method | Results | Patient Satisfaction |
|-------------------|--------------------|---------|----------------------|
| Douglas\[^{19}\]  | Clinician report   | Case 3: negligible stiffness | —                    |
| Moleman and Elliot \[^{31}\] | Parental Questionnaire | Difficulty cutting nail: 11 (29%) | —                    |
| Adani et al\[^{14}\] | — | Digit use “normal”: 34 (90%) | —                    |
| Kankaya et al\[^{27}\] | Clinician report | All patients used their hands normally | —                    |
| Daggregorio and Saint-Cast \[^{18}\] | Clinician report | All fingers were functional | —                    |
| Chen et al\[^{17}\] | Questionnaire | 4 (13.8%) experienced limitation in use of hand | —                    |
| Butler et al\[^{16}\] | Parental Questionnaire | 2 parents (5%) reported functional deficit | —                    |
| Idone et al\[^{25}\] | Clinician report | All patients were able to normally use their digits also for pinching and picking up small objects | —                    |
| Borrelli et al\[^{15}\] | Questionnaire | Time before using hand/finger in normal activities: 1–2 wk: 3 (5.9%) | Satisfaction with appearance mean 4/5 |
| Losco et al\[^{30}\] | Questionnaire & objective | Mean Q-DASH score: 1.8 | Esthetic satisfaction: Excellent: 8 (57.1%) |

**Figure 2.** Mean percentage of composite graft survival/take/success\[^{10,14-22,26-29,31-34}\].

**Figure 3.** Mean revision rate\[^{10,15-21,23,24,27,30,32,33}\].
across the included studies, making comparisons of success rates difficult. As an example of this, a few studies define complete or partial take as success, while others do not. This is reflected in the broad range of success rates across the data which vary from 7.7%\[20\] to 93.5%\[17\]. Details of postoperative care such as assessments of recovery and postoperative instructions were also varied and could add significant variability. Despite this heterogeneity making it difficult to compare results and synthesize data across studies, the results from the 23 articles included in this review suggest that composite grafting is a successful management technique for distal fingertip amputations not for microsurgical reconstruction and often yields good functional and sensation outcomes. Cosmetic outcomes may not be optimal; however, this must be considered against the outcomes from primary closure of the stump, which results in loss of the nail complex. Future studies should be additive or adopt previously used classification systems, such as the Ishikawa, which has the advantage of detailing the angle of amputation, which may be significant. Furthermore, future work should use clear definitions of graft success to facilitate homogeneity.

Conclusions

Composite grafting may be a useful technique in the management of distal fingertip amputations in adults and children when microsurgical anastomosis is not possible and may yield good functional and sensation outcomes with good patient satisfaction. However, cosmetic outcomes are less successful, with nail deformity and digit shortening commonly reported. Adverse outcomes are also commonly reported. Current available evidence suggests that composite grafting success is higher in children with more distal amputation levels by a cut mechanism who undergo composite grafting within a few hours from injury. The current available data on composite grafting for distal fingertip amputations is extremely heterogeneous and synthesis of results is difficult for this reason. Little standardization exists for detailing injury, amputation, operative or follow-up information and several classifications systems are used. How optimal healing is defined is also a major limitation to interpreting the success of composite grafting. This is reflected in the rates of composite graft take, which vary widely. Further research should aim to address this by using standardized methods of collecting data.

Declarations

Informed consent: Not applicable

Ethical approval

None.

Sources of funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Author contribution

A.G. and R.A: conceived the idea for the review. M.L., M.B., and V.S.: performed the search and screening. M.L., M.B., and A.G.: drafted the manuscript. All authors reviewed the final manuscript.

Conflicts of interest disclosure

The authors declare that they have no financial conflict of interest with regard to the content of this report.

Research registration unique identifying number (UIN)

Trial registration number: reviewregistry655.

Guarantor

Aina V.H. Greig.

References

[1] Mimi R, Borrelli MLL, Agha R, et al. Composite grafts for fingertip amputations: a systematic review protocol. Int J Surg Protoc 2019;16:1–4.
[2] Fassler PR. Fingertip injuries: evaluation and treatment. J Am Acad Orthop Surg 1996;4:84–92.
[3] Fetter-zarzeka A, Joseph MM. Hand and fingertip injuries in children. Pediatr Emerg Care 2002;18:341–5.
[4] Gellman H. Fingertip-nail bed injuries in children: current concepts and controversies of treatment. J Craniofac Surg 2009;20:1033–5.
[5] Lemmon JA, Janis JE, Rohrich RJ. Soft-tissue injuries of the fingertip: methods of evaluation and treatment. An algorithmic approach. Plast Reconstr Surg 2008;122:105e–17e.
[6] Martin C, del Pino JG. Controversies in the treatment of fingertip amputations: conservative versus surgical reconstruction. Clin Orthop Relat Res 1998;353:63–73.
[7] Hattori Y, Doi K, Sakamoto S, et al. Fingertip replantation. J Hand Surg 2007;32:548–55.
[8] Sebastin SJ, Chung KC. A systematic review of the outcomes of replantation of distal digital amputation. Plast Reconstr Surg 2011;128:723.
[9] Wang K, Sears ED, Shauver MJ, et al. A systematic review of outcomes of revision amputation treatment for fingertip amputations. Hand 2013;8:139–45.
[10] 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;6:764–70.
[11] Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, eds. Cochrane Handbook for Systematic Reviews of Interventions (Vol 5), 2nd Edition. Chichester (UK): John Wiley & Sons; 2019.
[12] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151:264–9.
[13] OCEBM Levels of Evidence Working Group. The Oxford 2011 Levels of Evidence. Oxford Centre for Evidence-Based Medicine. Available at: http://www.cebm.net/index.aspx?o=5633. Accessed August 31, 2020.
[14] Adani R, Marcoccio I, Tarallo L. Treatment of fingertips amputation using the Hirase technique. Hand Surgery 2003;8:257–64.
[15] Borrelli MR, Dupre S, Mediratta S, et al. Composite grafts for pediatric fingertip amputations: a retrospective case series of 100 patients. Plast Reconstr Surg Glob Open 2018;6:e1843.
[16] Butler D, Murugesan L, Ruston J, et al. The outcomes of digital tip amputation replacement as a composite graft in a paediatric population. J Hand Surg Eur Vol 2016;41:164–70.
[17] Chen S-Y, Wang C-H, Fu J-P, et al. Composite grafting for traumatic fingertip amputation in adults: technique reinforcement and experience in 31 digits. J Trauma Acute Care Surg 2011;70:148–53.
[18] Dagregorio G, Saint-Cast Y. Composite graft replacement of digital tips in adults. Orthopedics 2006;29:22–4.
[19] Douglas B. Successful replacement of completely avulsed portions of fingers as composite grafts. Plast Reconstr Surg 1959;23:213–25.
[20] Eberlin KR, Busa K, Bae DS, et al. Composite grafting for pediatric fingertip injuries. Hand (N Y) 2015;10:28–33.
[21] Eo S, Doh G, Lim S, et al. Analysis of the risk factors that determine composite graft survival for fingertip amputation. J Hand Surg Eur Vol 2018;43:1030–5.
[22] Hirase Y. Postoperative cooling enhances composite graft survival in nasal-alar and fingertip reconstruction. Br J Plas Surg 1993;46:707–11.
[23] Hirase Y. Salvage of fingertip amputated at nail level: new surgical principles and treatments. Ann Plast Surg 1997;38:151–7.
[24] Idone F, Sisti A, Tassanati J, et al. Cooling composite graft for distal finger amputation: a reliable alternative to microsurgery implantation. In Vivo 2016;30:501–5.
[25] Imazumi A, Ishida K, Arashiro K, et al. Validity of exploration for suitable vessels for replantation in the distal fingertip amputation in early childhood: re plantation or composite graft. J Plas Surg Hand Surg 2013;47:258–62.
[26] Kankaya Y, Ulusoy MG, Sungur N, et al. An alternative technique for microsurgically unplantable fingertip amputations. Ann Plas Surg 2006;57:545–51.
[27] Kiuchi T, Shimizu Y, Nagasao T, et al. Composite grafting for distal digital amputation with respect to injury type and amputation level. J Plas Surg Hand Surg 2015;49:224–8.
[28] Kusuhara H, Itani Y, Isgoi 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;36:55–60.
[29] Losco L, Kaucylyte J, Delia G, et al. Back to basics with distal thumb reconstruction. Easy management of the incomplete amputation. J Invest Surg 2019;1–7. doi: 10.1080/08941939.2019.1672840
[30] Moisem N, Elliot D. Composite graft replacement of digital tips 2. A study in children. J Hand Surg Br Eur Vol 1997;22:346–52.
[31] Murphy AD, Keating CP, Penington A, et al. Paediatric fingertip composite grafts: Do they all go black? J Plas Reconstr Aesthet Surg 2017;70:173–7.
[32] Rose EH, Norris MS, Kowalski TA, et al. The ‘cap’ technique: non-microsurgical reattachment of fingertip amputations. J Hand Surg 1989;14:513–8.
[33] Son D, Han K, Chang DW. Extending the limits of fingertip composite grafting with moist-exposed dressing. Int Wound J 2005;2:315–21.
[34] Usoro-Biaarda FG, Wallace CG, Baker R. Post-traumatic composite graft fingertip replacement in both adults and children. Eur J Plast Surg 2009;32:229–33.
[35] Ishikawa K, Ogawa Y, Soeda H, et al. A new classification of the amputation level for the distal part of the finger. J Jpn Soc Reconstr Microsurg 1990;3:54–62.
[36] Allen MJ. Conservative management of finger tip injuries in adults. Hand 1980;12:257–65.
[37] Das S, Brown HG. Management of lost finger tips in children. Hand 1978;10:16–27.
[38] Dumontier C, Tubiana R. Physical Examination of the Hand. In: Allen MJ, ed. Plastic Surgery. Philadelphia, PA: Mosby; 2010:749–54.
[39] Haefeli M, Elfering A, Pain assessment. Eur Spine J 2006;15:S17–24.
[40] Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand)[corrected]: the Upper Extremity Collaborative Group (UECG). Am J Ind Med 1996;29:602–8.
[41] Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (Quick DASH): validity and reliability based on responses within the full-length DASH. BMC Musculoskelet Disord 2006;7:44.
[42] Barakat M, Field J, Taylor J. The range of movement of the thumb. Hand 2013;8:179–82.