Systematic Review and/or Meta-analysis

INTERNATIONAL JOURNAL OF SURGERY: SHORT REPORTS

OPEN

Composite grafts for fingertip amputations: a systematic review

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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[1,2]. 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[3,4]. Treatment aims to restore a painless, minimally shortened digit with durable and sensate skin, preserved function, and a satisfactory esthetic outcome[2,5,6].

Microsurgical replantation can produce superior functional and esthetic outcomes[7–9], but arterial or venous anastomoses are impossible in certain avulsion amputations or distal crush injuries[7], and in small children whose vessels are of smaller diameter[10]. Composite grafting, where the amputated tip is directly sutured onto the proximal stump, is an alternative option to reconstruct a non-replantable amputated fingertip. The composite graft is initially nourished by diffusion, and later through neovascularization. Composite grafting is a simple time- and cost-effective technique. It may preserve digital length, and in some cases restore sensory and motor function and a near-normal nail complex[10].

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[11] and is

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This manuscript has been peer reviewed.

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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International Journal of Surgery Short Reports (2021) 6:e17

Received 31 August 2020; Accepted 14 November 2020

Published online 2 April 2021

http://dx.doi.org/10.1097/SR9.0000000000000017

compliant with PRISMA guidelines[12]. A systematic review protocol was published[1], and the systematic review was registered a priori: https://www.researchregistry.com.

Criteria

Studies included

Original research studies of levels 1–5 of the Oxford Centre for Evidence-based Medicine[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[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.

Table 1

Study inclusion and exclusion criteria.

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

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 (**Fig. 1**)[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=4), 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[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[29] which was graded as "moderate".

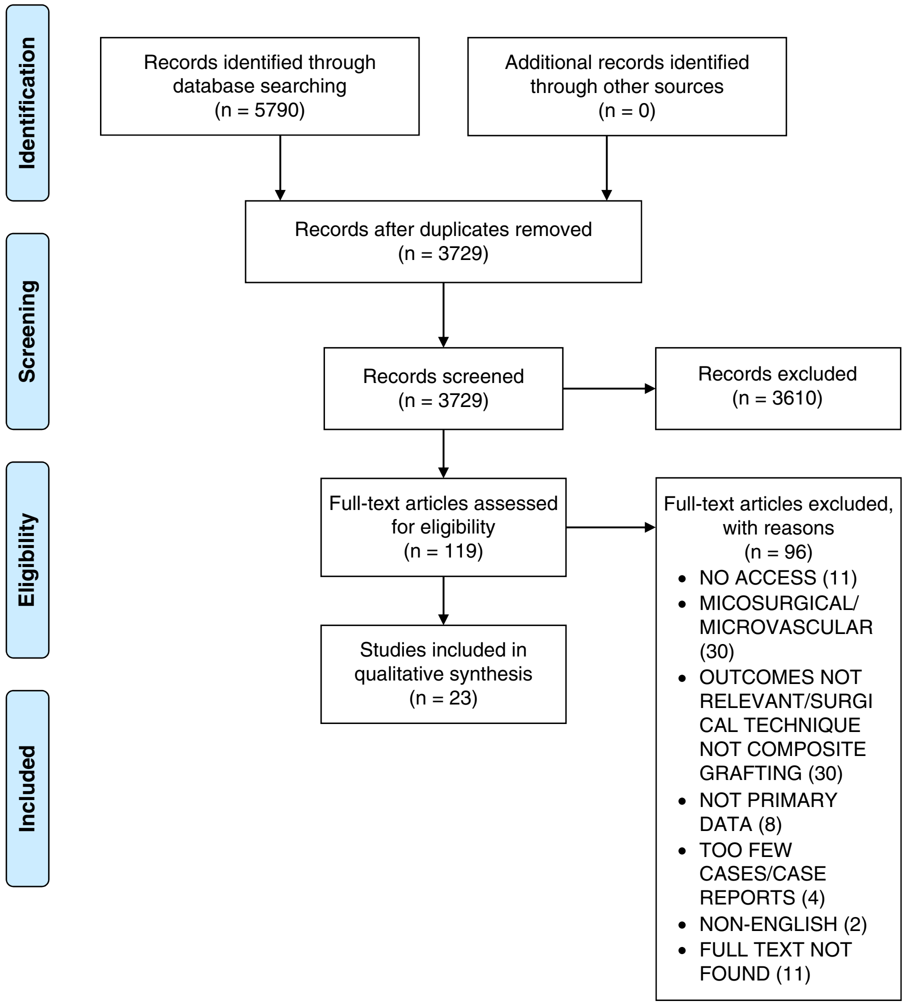

Figure 1. Flow diagram showing the number of articles at each step of screening[12].

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[17,22,24,28,34].

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]. 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.

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[10,14,17–25,27,28,30,33–35].

Table 3

Demographic characteristics of included articles.

References	Location	Oxford Level of Evidence	Grade Score	No. of Patients
Douglas[19]	USA	IV	Very low	17
Rose et al[33]	USA	V	Very low	7
Hirase[23]	Japan	IV	Very low	32
Hirase[24]	Japan	IV	Very low	10
Moiemen and Elliot[31]	UK	IV	Very low	50
Adani et al[14]	Italy	IV	Very low	7
Heistein and Cook[22]	USA	III	Very low	53
Son et al[34]	South Korea	III	Very low	56
Kankaya et al[27]	Turkey	IV	Very low	23
Dagregorio and Saint-Cast[18]	France	IV	Very low	19
Urso-Baiarda et al[35]	UK	IV	Very low	108 (digits)
Eo et al[10]	SouthKorea	IV	Very low	24
Chen et al[17]	Taiwan	IV	Very low	27
Kusuhara et al[29]	Japan	I	Moderate	18 (digits)
Imaizumi et al[26]	Japan	IV	Very low	10
Butler et al[16]	UK	III	Very low	97
Eberlin et al[20]	USA	IV	Very low	39
Kiuchi et al[28]	Japan	IV	Very low	27
Idone et al[25]	Italy	IV	Very low	8
Murphy et al[32]	Australia	IV	Very low	96
Eo et al[21]	Korea	IV	Very low	94
Borrelli et al[15]	UK	IV	Very low	100
Losco et al[30]	Italy	IV	Very low	14

Smoking and comorbidity status were only reported in 7 of all the 23 articles reviewed[10,15,21,22,27,30,35]. However, when analyzed as a factor, smoking status significantly decreased the chance of fingertip graft survival; Heistein 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[17,27,33]. 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[14–18,20,22,25–27,31] 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 resuturing the nail bed[22,26,31]. Dagregorio and Saint-Cas[18] 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[17,27,33]. Heistein 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[15,17,27,28,33] 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[10,14,16,19,21–25,27,31,32]. 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]. Ten articles stratified graft survival into complete, partial or no survival[10,14,19,22,25,28–30,33,35]; however, 3 articles binarized[21,26,34] graft survival into "success" or "failure," and 7 1articles 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[17,20,21,23,24,27,30,32,33] 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%[23]. 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]. Questionnaires were used in 3 studies[15,16,31], and the remaining eight studies were clinician reported/objectively stated (**Table 7**). Of the 4 studies reporting on finger shortening measurements, the mean digit shortening was 5.9 mm[15,27,30,33]. 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[15] 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[10,14–17,19,25,27,30,31,33] (**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

Table 4

Amputation details and patient demographics.

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[24]	10	—	—	11	—	—	Hirase	DP 1: 6 DP 2a: 3 DP 2b: 2	1 y
Moiemen and Elliot[31]	50	5.7 (1–14)	12	50	—	Crush (door): 38 Crush (other): 9 Cut: 3	Modified Ishikawa	Level 1a: 4 Level 1b: 17 Level 2: 21 Level 3: 8	14.8
Adani et al[14]	7	24 (4–60)	1	7	—	Crush (door): 3 Crush (other): 3 Sharp amputation: 1	Hirase	Level 1: 1 Level 2: 3 Level 3: 2 1 amputation of finger pulp	2 y total
Heistein and Cook[22]	53	28 (1–71)	19	57	Smokers: 12 Alcohol: 23 Diabetes: 6	Crush: 19 Avulsion: 18 Guillotine: 16	Other	DP1: 36 DP2: 21	All had 12 wk follow up
Son et al[34]	56	28 (1–60)	13	60	—	Crush: 32 Guillotine: 24 Avulsion: 4	Other (Relation to lanula)	Zone I: 31 Zone II: 14 Zone III: 15	Checked at 2 wk
Kankaya et al[27]	23	32.41 (1.5–57)	4	23	Smokers: 8 Diabetes: 3 Hypertension: 1 Diabetes & hypertension: 1	—	Hirase	Zone 1: 2 Zone 2: 15 Zone 3: 6	12.4
Dagregorio and Saint-Cast[18]	19	39.7 (25–58)	7	19	—	Crush (transverse): 3 Crush (oblique): 3 Sharp (oblique): 8 Sharp (transverse): 5	Ishikawa	Level I: 8 Level II: 7 Level III: 4	All checked 9–12 mo
Urso-Baiarda et al[35]	—	Median: 5.9	—	108	No diabetes* Smoking: 21% adults Steroid use: 2% children, 5% adults	—	Ishikawa	—	Mean healing time Children: 68 d Adults: 82 d
Eo et al[10]	24	31.2 (1–67)	13	24	Smokers: 5 No diabetes or atherosclerosis	Crush: 15 Cut: 9	Das & Brown	Type 1: 13 Type 2: 10 Type 3: 1	8–17
Chen et al[17]	27	40.5 (20–65)	5	31	—	Crush: 21 Cut: 10	Allen	Type 2: 9 Type 3: 22	11.7
Kusuhara et al[29]	—	—	—	18	—	—	Ishikawa	All subzone 2	All checked at 3 wk
Imaizumi et al[26]	10	Distal: 4.8 Middle: 3 (1.67–6.75)	—	10	—	All avulsion/crush	Modified Allen	Distal: 3 Middle: 7	2.63

Table 4

(*Continued*)

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 Cut: 3	Moeimen's modification of Ishikawa's classification	Level 1a: 12 Level 1b: 51 Level 2: 32 Level 3: 2	1.8 mean
Eberlin et al[20]	39	5.9 (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 Subzone 2: 17 Subzone 3: 6 Subzone 4: 5	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 Level 2: 3 Level 3: 3	10
Murphy et al[32]	96	Median: 2.4 (0–16)	57	96	—	Crush: 89 Laceration: 4 Not recorded: 3	Moeimen's modification of Ishikawa's classification	*Level 1a: 16 Level 1b: 36 Level 2: 13 Level 3: 2	2.23
Eo et al[21]	94	39 (1–68)	25	94	Smoker: 34 Nonsmoker: 60	Cut: 60 Crush: 34	Das & Brown	Type 1: 44 Type 2: 31 Type 3: 19	Mean 3
Borrelli et al[15]	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 Level 1b: 26 Level 2: 42 Level 3: 16 Oblique: 13	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

*As documented in original article.

DIPJ indicates distal interphalangeal joint; HIV, Human Immunodeficiency Virus; IPJ, interphalangeal joint; NAI, nonaccidental injury.

Table 5

Operative technique and graft survival outcomes.

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	—	—	Yes	Ointment	CS: 71 PS: 29
Hirase[23]	Classic	—	—	—	—	—	—	PGE 1	Variable	—	—	No cooling S: 23.8 Cooling S: 81.8
Hirase[24]	Classic	—	—	—	—	—	No	PGE 1	Yes	—	—	S: 90.9
Moiemen and Elliot[31]	Classic	Complete: 3.9 Partial: 7 Failed: 7.8	Nail removed and nail bed sutured	—	No	No	Kirschner wire in 3 cases	—	Variable preoperative	Yes (nail)	Yes	CT: 22 PT: 52 F: 13
Adani et al[14]	Classic	—	Sutured	—	—	—	Variable longitudinal Kirschner	No	Yes	—	Yes	CS: 57.1 PS: 28.6 NS: 14.3
Heistein and Cook[22]	Classic	2.27	Nail removed and nail bed sutured	No	No	—	Variable Kirschner wire	No	Variable preoperative	Yes (nail)	Yes	CS: 52.6 PS: 31.6 NS: 15.8
Son et al[34]	Classic	—	—	—	—	—	—	—	—	Yes	Ointment	S: 70 F: 30
kankaya et al[27]	Cap	—	Yes	Yes	Yes	Yes	—	Tetanus prophylaxis	Variable	—	Yes	CT: 73.9 PT: 17.4 NT: 8.7
Dagregorio and Saint-Cast[18]	Classic	All <4 h	Nail bed sutured 7-0	—	Variable	—	Variable needle	—	—	Yes (nail)	—	Success: 52.6 PT: 15.7 F: 31.6
Urso-Baiarda et al[35]	—	Median 6.5	—	—	—	—	—	—	—	—	—	CS/PS: Adults: 85.7 Children: 88.5
Eo et al[10]	Classic	5	—	—	—	—	—	Lipo PGE 1	Yes	—	Wash & ointment	CS: 91.7
Chen et al[17]	Cap	—	Yes	Yes	Yes	Variable	—	—	—	Yes	—	CT: 93.5
Kusuhara et al[29]	Classic	—	—	—	—	—	—	b-FGF	—	—	—	Tissue survival: 100%: 27.8 >75%: 33.3 50-75%: 11.1 <50%: 27.8
Imaizumi et al[26]	Classic	—	Nail removed and nail bed sutured*	—	—	—	Variable Kirschner wire*	No	—	—	—	*Distal* Success: 33.3 *Middle* Success: 57
Butler et al[16]	Classic	Complete: 6.5 Partial: 7.2 Nil: 6.7	Variable	—	Variable	Small fragments	—	No	Preoperative	—	Yes	CT: 10 PT: 34 NT: 56
Eberlin et al[20]	Classic	—	If necessary	—	No	Small fragments	—	No	No	Yes	Yes	CT: 7.7 PT: 59 NT: 33.5

Table 5

(Continued)

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) %
Kiuchi et al[28]	Classic	—	—	—	—	Yes	—	19 PGE 1 drips	—	—	Variable	CS: 18.8 PS: 53.1 NS: 28.1
Idone et al[25]	Classic	—	Sutured	—	—	—	Longitudinal Kirschner	No	Yes	—	—	CS: 75 PS: 25
Murphy et al[32]	Classic	7.5 median	Removed	—	No	Small fragments	—	—	Variable preoperative	Yes	Yes	NT: 31 PT: 52 CT: 16
Eo et al[21]	Classic	4	—	—	—	—	Kirschner wire	Lipo PGE 1	Yes	—	Ointment	S: 89 F: 11
Borrelli et al[15]	Classic	< 6 h: 25%	Variable	—	Variable	Yes	Kirschner wire use in 1 case	—	—	Variable	Yes	CS: 13 PS: 46 NS: 41
Losco et al[30]	Classic	2.2	—	—	—	—	20-G needle	—	—	—	Yes	Normal healing: 60 Minimal necrosis: 40

*Method as reported by Moiemen.
b-FGF indicates basic fibroblast growth factor; CS, complete survival; CT, complete take; F, failed; GT, graft take; Lipo, liposomal; NS, no survival, NT, no take; PGE-1, Prostaglandin E 1; PS, partial survival; PT, partial take; S, survived/successful.

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[14] 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 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

Table 6

Adverse outcomes.

References	Adverse Outcomes	Revision Operation (%)	Other Details
Douglas[19]	1 infection 1 ulcer	11.8	—
Rose et al[33]	2 digits small areas necrosis	0	Superficial eschar developed in several
Hirase[23]	*Cooling* 1 necrosis 1 partial necrosis *Non-cooling* —	56.3	*Cooling* 1 debridement 1 finger pulp reverse vascular pedicle digital island flap reconstruction *Noncooling* 16 skin grafts/flaps
Hirase[24]	1 partial necrosis	9.1	1 split skin graft
Moiemen and Elliot[31]	—	—	—
Adani et al[14]	—	—	—
Heistein and Cook[22]	No infections or serious complications	—	—
Son et al[34]	—	—	—
Kankaya et al[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
Dagregorio and Saint-Cast[18]	2 cases of partial take healed by secondary intention	5.3	1 cross finger flap adjunct
Urso-Baiarda et al[35]	—	—	—
Eo et al[10]	Scab formation was inevitable happened in 11 of 24	8.3	1 revision flap (cross finger) 1 Atasoy's volar V-Y advancement flap
Chen et al[17]	2 graft necroses	6.5	1 thenar flap 1 volar V-Y advancement flap
Kusuhara et al[29]	—	—	—
Imaizumi et al[26]	No significant complications	—	No blood transfusions
Butler et al[16]	11 post-operative infection	17 (re-operation or infection)	More proximal amputation significantly associated with infection
Eberlin et al[20]	Indications for revision: patient/family dissatisfaction, persistent pain, or aesthetic deformity	10	2 operative debridement of nonviable tissue 1 debridement and revision amputation 1 debridement and V-Y advancement flap closure
Kiuchi et al[28]	"There were no complications that affected graft survival"	—	—
Idone et al[25]	—	—	—
Murphy et al[32]	1 infected necrotic graft 1 necrotic graft	2	1 debridement 1 debridement with local flap
Eo et al[21]	—	10.6	5 stump revisions & no reconstruction 3 thenar flaps 2 distal abdominal flaps
Borrelli et al[15]	17 infections 9 wound healing complications 4 psychological complications 1 hypersensitivity and phantom pain	9	5 debridements for infection/ necrotic material 4 terminalisations of exposed bone
Losco et al[30]	Minimal necrosis (<1 cm^2) in 6	0	Cases of partial necrosis were managed on outpatient basis

(level 4)[10,14,15,17–21,23,25–28,30–32,35]. Another factor limiting study was the low participant number. A minority of available studies included > 50 patients[15,16,21,22,31,32,34,35].

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[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[22] found that smoking was an independent factor associated with poorer graft healing. Better graft survival has been linked to decreased time to operation[31], lower age[15,16], clean-cut injuries[21,28], and more distal amputation levels[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

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 4th: very little shortening 6th: nail growth normal slight scar	Case 3: slight thinning of the pad, but finger was normal
Rose et al[33]	Objective	—	6	Flat nail growth returned in all digits	Pulp pinch averaged 67%
Moiemen and Elliot[31]	Parental Questionnaire	Short digit: 28 (74%) Hooked nail: 22 (58%) Flat pulp: 23 (61%)	—	—	Response rate: 76%
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[10]	Clinician reported	—	—	"acceptable appearance"	—
Butler et al[16]	Parental questionnaire	Abnormal appearance: 28 (67%) Pulp abnormal: 17 (40%)	—	Nail hooked: 20 (48%) 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[32]	Clinician reported	—	—	3 hook nail deformity	—
Borrelli et al[15]	Questionnaire & objective	Finger shortening: 29 (56.9%) Normal nail growth: 26 (51%) Abnormal nail curve: 19 (37.3%) Nail shortening: 47 Absent nail: 3 Normal appearance outcome: Median 3.5/5	3.93	1 hook nail	—
Losco et al[30]	Objective	—	6.9	"No nail lamina deformity was reported"	—

Table 8

Sensory outcomes.

References	Sensation Assessment Method	Two-point Discrimination (mean, mm)	Time Point Assessed	Questionnaire Answers/Details
Douglas[19]	Clinician report	—	—	Approximately 3 wk for sensation to return Partially returned in 72h in some
Rose et al[33]	2PD	6.5	—	—
Moiemen and Elliot[31]	Parental Questionnaire	—	—	Tender tip: 10 (26%) Pain cutting nail: 8 (21%)
Adani et al[14]	Clinician report & 2PD	<7 in all patients	2 y	None complained of dysesthesia or cold symptoms
Kankaya et al[27]	Questionnaire & 2PD	7.26	6 mo	Zone I (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[10]	2PD	5.5	—	Some complained of persistent paraesthesia
Chen et al[17]	Questionnaire & 2PD	6.3	6 mo	Numbness over the fingertip: 19 (65.5%) Fingertip tenderness: 4 (13.8%)
Butler et al[16]	Parental Questionnaire	—	—	Scar tender: 3 (7%) Cold intolerance: 7 (17%) Hypersensitive: 3 (7%)
Idone et al[25]	2PD	<5 in all	—	No patient complained of dysesthesia or cold intolerance
Borrelli et al[15]	Questionnaire	—	—	Reduced: 14 (27.5%) Increased: 10 (19.6%) Normal: 27 (52.9%) Cold intolerance: 9 (17.6%) Numbness: 8 (15.7%) Tender tip/scar: 15 (29.4%)
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.

Table 9

Functional outcomes and patient satisfaction.

References	Measurement Method	Results	Patient Satisfaction
Douglas[19]	Clinician report	Case 3: negligible stiffness Case 4: ankylosis at distal joint	—
Moiemen and Elliot[31]	Parental Questionnaire	Difficulty cutting nail: 11 (29%) Digit use "normal": 34 (90%)	—
Adani et al[14]	—	All patients used their hands normally	—
Kankaya et al[27]	Clinician report	—	Zone 1: full functional and aesthetic satisfaction Zone 2: satisfaction with aesthetic and sensation outcomes Zone 3: —
Dagregorio and Saint-Cast[18]	Clinician report	All fingers were functional	—
Chen et al[17]	Questionnaire	4 (13.8%) experienced limitation in use of hand	Very satisfied: 24 (82.8%) Moderately satisfied: 2 (6.9%) Slightly satisfied: 1 (3.4%) Completely unsatisfied: 2 (6.9%)
Butler et al[16]	Parental Questionnaire	2 parents (5%) reported functional deficit	Parents reported ∼45% complete graft survival
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%) 2–4 wk: 11 (21.6%) 1–2 mo: 10 (19.6) 2–6 mo: 18 (35.3%) > 6 mo: 9 (17.6%)	Satisfaction with appearance mean 4/5
Losco et al[30]	Questionnaire & objective	Mean Q-DASH score: 1.8 Mean motion at IPJ: 48 degrees All patients returned to work in 4.3 wk	Esthetic satisfaction: Excellent: 8 (57.1%) Good: 5 (35.7%) Fair: 1 (7.1%)

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 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

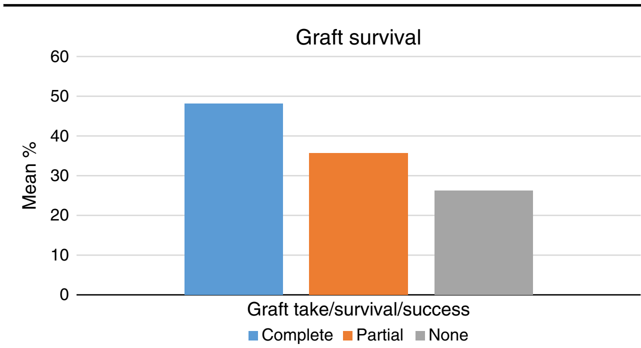

Figure 2. Mean percentage of composite graft survival/take/success[10,14–22,25,27–29,31–34].

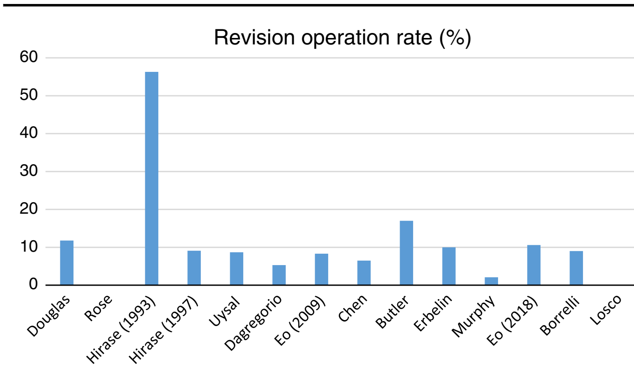

Figure 3. Mean revision rate[10,15–21,23,24,27,30,32,33].

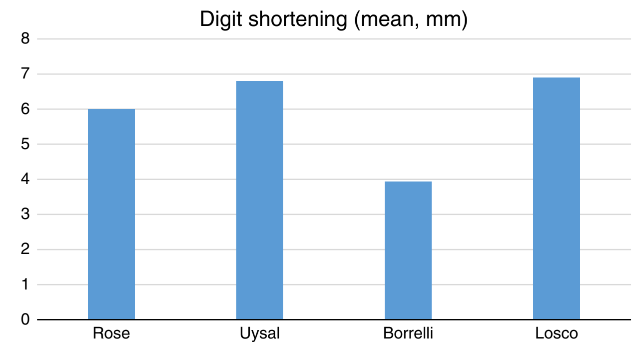

Figure 4. Mean digit shortening[15,27,30,33].

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 heterogenous 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.

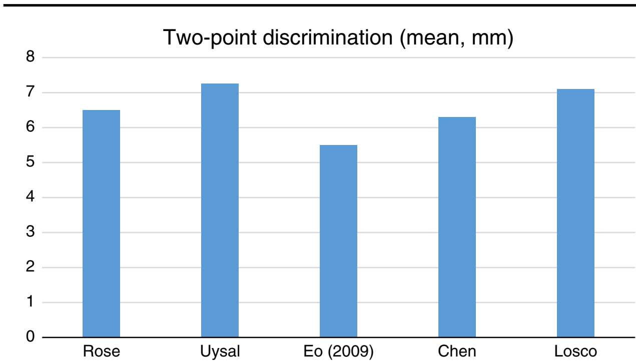

Figure 5. Mean 2-point discrimination[10,17,27,30,33].

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.

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