Outcome of "Vascularized Bone Graft Spare Parts" Reconstruction of Segmental Metacarpal Deficits of Hand

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ABSTRACT

Objective: To determine the radiological and functional outcome of "vascularized bone graft spare parts" fashioned from severely damaged but viable parts of the hand and used for reconstruction of hand defects.

Methods: This descriptive study was conducted from 3rd January 2014 to 25th January 2018 in Millat Orthopaedic and Trauma Surgery Hospital Sargodha. All patients with traumatic hand defects fulfilling the inclusion criteria were reconstructed with vascularized bone graft spare parts technique. Patients were followed regularly for viability of graft, bone union and functions of the hand.

Results: A total of 6 patients with mean age 33.3 years (range 19 to 45 years) were included in our study. The aetiology of hand trauma was saw cut in 2(33.3%), crush injury in 2(33.3%), firearm in 1(16.6%) and sepsis in 1(16.6%) patient. Segmental defects in the first metacarpal were present in 3(50%) patients, first and third metacarpal in 2(33.3%) and third metacarpal in 1(16.6%) patient. Vascularized bone graft spare part pedicle of index phalangeal osteocutaneous was used in 6 patients, 2nd metacarpal osseous in 1(16.6%) and ring phalangeal osteocutaneous in 1 (16.6%). The average length of harvested bone graft used was 4.13cm (Range 3 to 5.5cm). All the flaps survived and bones united. Acceptable hand functions were restored in 4(66.6%) and mangled hand in 2(33.3%) patients. All patients resumed their work status and functional results were satisfactory.

Conclusion: Severely damaged and complex hand injuries treated with vascularized bone graft spare parts technique had good radiological and functional outcome. We, therefore recommend that vascularized bone graft pedicle spare parts of a severely injured hand should be innovated as a possible source for one stage reconstruction of the hand.

Keywords: Digital spare parts, segmental metacarpal deficits, single or double digital artery basis, vascularized bone grafts.

This article may be cited as: Cheema MA, Cheema HA, Bashir H. Outcome of "Vascularized Bone Graft Spare Parts" Reconstruction of Segmental Metacarpal Deficits of Hand.J Pak Orthop Assoc 2019;31(3):

INTRODUCTION

Treatment of large, complex metacarpal bone deficits in the hand requires a sophisticated management strategy with a significant challenge for a surgeon. The prerequisites for reconstruction to salvage the hand and restore its functions need careful planning with due consideration to the type and size of flap, careful execution and resultant donor-site morbidity. Treatment options ranging from complex reconstruction to amputation, non-vascularized cortico-cancellous bone graft, distant pedicle flap coverage, osteo-cutaneous pedicle, free flaps,[1-4] elongation via distraction osteogenesis,[5] and "vascularized bone graft spare parts" fashioned from severely damaged but viable parts of the hand. Conventional bone grafts have substantial problems with fatigue fracture and resorption of necrotic bone due to inadequate bone graft incorporation by revascularization process. Vascularized forearm bone grafts or free bone transfers are demanding and time-consuming procedures, and have morbidity of the donor site,[6-7] or damaging the vasculature of the hand.[8]Metacarpal elongation via distraction osteogenesis is also time consuming and cumbersome for the patients because of the external fixator in situ.[5]

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A severely damaged digit which cannot be restored to usefulness (i.e., functionally worthless or detrimental to the over-all function of the hand) but when it may contribute valuable tissue which can be used in the rebuilding of the rest of the hand is considered as a biological spare part. When the nature of injury has led to biological spare parts of hand, they can be the only reliable alternative left to fulfil the requirements of complex reconstruction by moving them with their blood supply undisturbed to an adjacent area. Vascularized bone graft spare parts transplantation allows intercalated defect reconstruction with alive and dynamic tissue in its new site. It has the advantages of reconstructing composite tissue loss in one procedure without donor-site morbidity while preserving as much function as possible.

This study illustrated the radiological and functional outcome of "vascularized bone graft spare parts" fashioned from severely damaged but viable parts of the hand and used for reconstruction of hand defects. The ultimate aim was early restoration of sufficient form and functions of activities of daily living and return to work.

METHODS

We conducted this descriptive study in Millat Orthopaedic and Trauma Surgery Hospital Sargodha from 3rd January 2014 to 25th January 2018. All patients presented with segmental metacarpal bone loss with or without associated soft tissue deficits were enrolled in this study. Patients with complete amputations of all the digits and requiring microvascular replantation were excluded. The study was approved by the Ethical Review Board of the hospital. Informed consent was taken from all the participants. A severely damaged digit which could not be restored to usefulness (i.e., functionally worthless or detrimental to the over-all function of the hand), but when it may contribute valuable tissue which could be used in the rebuilding of the rest of the hand was considered as biological spare part. History, physical examination and x ray of the hand was taken in all cases. All patients were operated under general anaesthesia and tourniquet control. Vascularized bone graft spare parts used were osteo-cutaneous from index finger, ring finger and osseous from second metacarpal. All flaps were transferred as proximally based osseous/osseo-fascial/osseo-cutaneous island or cutaneous pedicle. Additional soft tissue procedures performed to get the large wounds healed were abdominal pedicle flap, posterior interosseous flap, and fillet flaps. Patients were followed regularly for viability of graft, bone union and functions of the hand monthly for six months. Immediately after healing of wounds patients were subjected to hand physical therapy. A hand having three fingers with near normal length, near normal sensation, and a functional thumb was considered an "acceptable hand," whereas, an injury resulting or potentially resulting in a hand with a function less than an acceptable hand was labelled a mangled hand. SPSS version 22 was used for analyzing the data. Quantitative variables were represented as mean while qualitative as frequencies and percentages. Data presented in table where necessary.

RESULTS

The total number of patients in our study was 6 with mean age 33.3 years (range 19 to 45 years). The aetiology of hand trauma was saw cut in 2(33.3%),crush injury in 2(33.3%),firearm in 1(16.6%) and sepsis in 1(16.6%) patient. Segmental defects in the first metacarpal were present in 3(50%) patients, first and third metacarpal in 2(33.3%) and third metacarpal in 1(16.6%) patient. Vascularized bone graft spare part pedicle of index phalangeal osteocutaneous was used in 6 patients, 2nd metacarpal osseous in 1(16.6%) and ring phalangeal osteocutaneous in 1 (16.6%). Reconstruction with vascularized bone graft spare parts was done immediately after injury in five cases and three months after in an infective case after prior sequestrectomy of first metacarpal chronic osteomyelitis. Additional soft tissue procedures performed to get the large wounds healed were abdominal pedicle flap in 4(66.6%) patients, posterior interosseous flap in 1(16.6%) and fillet flap from index finger in 1(16.6%), middle finger in 1(16.6%) and little finger in 1(16.6%) patient. In 2(33.3%) patients osteo-cutaneous index digit spare parts used for reconstruction of first metacarpal were de-dermized to get the large soft tissue wound covered by abdominal flap. In other 2(33.3%) patients (2+2=4 reconstructions) there were intercalated defects of first to third metacarpals and the worthless index digit was decided to use as vascularized bone graft spare parts by raising two osteo-cutaneous pedicles, one based on radial digital artery with distal and middle phalanges for first metacarpal bridging (DIPJ fused) and other based on

Table I. The demographic details and treatment options of our study subjects.

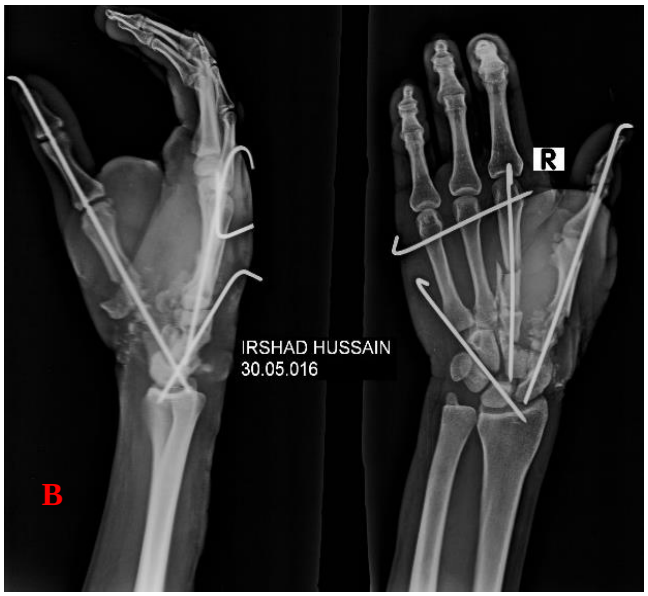
Patient	Sex	Age(years)	Mechanism of injury	Location of segmental defect in metacarpals	Vascularized bone graft spare part pedicle used	Length of bone graft (cm)	Additional procedures	Bone union(months)	Follow up period (months)
1	M	45	saw cut injury	1st metacarpal	Index proximal middle phalanx (PIPJ fused) osteo-cutaneous	5	Abdominal flap & middle finger fillet for coverage	3	6
2	M	44	saw cut injury	1st metacarpal	Index proximal middle phalanx (PIPJ fused) osseou-fascial	4	Abdominal flap & middle finger fillet for coverage	3	5.5
3	M	28	Firearm injury	1st metacarpal	Index middle & distal phalangeal (DIPJ fused) osteo-cutaneous based on radial digital artery	5.5	Abdominal flap & middle finger fillet for coverage	2	5.5
				3rd metacarpal	Index proximal phalanx osteo-cutaneous based on ulnar digital artery	3.5		3.5	3.5
4	M	26	Sepsis (flexor tenosynovitis of index finger with residual stiffness and 1st metacarpal osteomyelitis)	1st metacarpal	2nd metacarpal osseous	4.5	Posterior interosseous fascio-cutaneous intervening between two spare part pedicles	2.5	5
5	M	19	Crush injury	3rd metacarpal	Ring finger middle and distal phalangeal (DIPJ fused) osteo-cutaneous	4	Posterior interosseous fascio-cutaneous intervening between two spare part pedicles	2.5	5
6	M	38	Crush injury hand dorsum	1st metacarpal	Index finger middle and distal phalangeal (DIPJ fused) osteo-cutaneous based on radial digital artery	5	Index fillet for widened web space coverage	3.5	4
				3rd metacarpal	Index proximal phalanx osteo-cutaneous based on ulnar digital artery	4		4	4
Summary	Allmale	Range 19 to 45 Y (average 33.3)	Saw cut-2, crush injury-2, firearm-1 & sepsis-1	1st metacarpal -5, 3rd metacarpal-3	Index Phalangeal osteocutaneous-6; 2nd metacarpal osseous-1; ring phalangeal osteocutaneous-1	Range 3 to 5.5; average 4.13	Abdominal flap-4; PIF-1; index fillet-1, middle finger fillet-1 & ring finger fillet-1	Range 2 to 4 (average -3)	Range 3.5 to 6 (average-4.8)

ulnar digital artery with proximal phalanx to bridge third metacarpal. The average length of harvested bone graft used was 4.13cm (Range 3 to 5.5cm). The demographic details and treatment options of our study subjects are

shown in table I. All the flaps survived and bones united. Bone union was achieved in 2 to 3.5 months (average 2.7) after surgery. No donor site morbidity was reported. Additional bone grafting was not required in any patient. No congestion was seen after surgery. No delayed resorption of bone graft was seen at recipient site. Mean follow-up was 4.8 months with a range of 3.5 to 6 months. Acceptable hand functions were restored in 4(66.6%) and mangled hand in 2(33.3%) patients. All patients resumed their work status and functional results were satisfactory. Some of our cases are shown in figures I to III. No patient was lost to follow up in our study.

Case I (A). A 28-year-old male with a gunshot injury to his right dominant hand.

I (B). Reconstruction of thumb from Index finger (Spare Part)



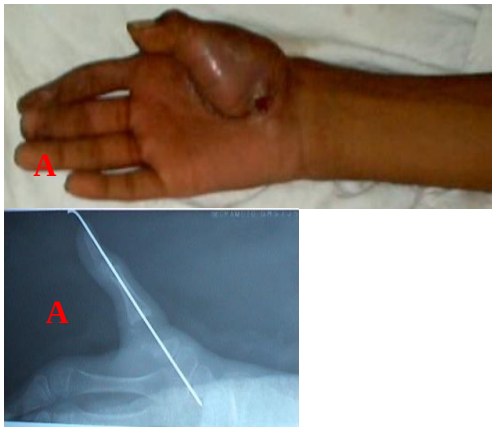
I (C). Clinical appearance with viable graft.

I(D).Radiological union of metacarpal

I(E). Functional position of the hand.

Case II (A). A 24-year-old male with straight stiff and scarred index finger and chronic osteomyelitis of the

thumb metacarpal There was scarred adduction contracture of the first web space with a wound. Sequestrectomy and thumb position was maintained with a K-wire

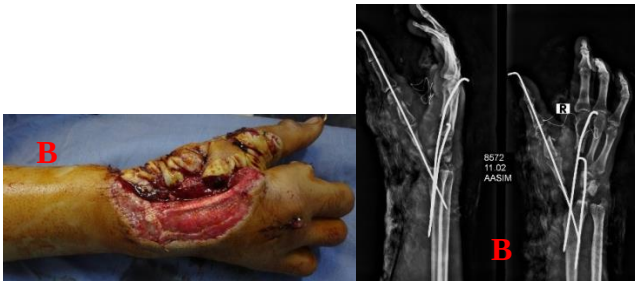


II (B). Second metacarpal was osteotomized at the base and an osseous fragment of 2nd metacarpal with a length of 4 cm was transposed as osseous vascularized bone to bridge intercalated defect of first metacarpal and axial 2 mm K wire was used for stabilization.

II (C). A fillet flap was developed from index finger that was transferred on the dorsal skin defect of deepened first web space

Case III (A). A 44-year-old-male, while working on a power saw machine, sustained an extensive injury to radio-dorsal side of hand and wrist of his dominant right hand.

III (B): Osteo-cutaneous vascularized bone graft pedicle from index digit (Spare Part) was fashioned and stabilization of the reconstructed thumb and wrist with 2mm K-wires.



III (C): The osteocutaneous flap was dedermized and converted into osseo-facial flap. The extensor indicis proprius (EIP) and the adjacent extensor digitorum communis (EDC) tendons were transferred to the thumb to reconstruct the extensor hood.

III (D). Clinical photograph showing complete coverage of the defect and healing of the wound with functional position of digits and hand.

DISCUSSION

In this study we had successfully reconstructed the severely injured hands presented with sever soft tissue loss by adopting the concept of biological "Vascularized bone Graft Spare Parts." The scavenged tissues were used as biological spare parts by "on the spot" planning for primary hand reconstruction from the tissues that were non-salvageable and will be thrown away. It had the primary advantage of avoiding the donor site morbidity of harvest from an uninjured distant region. Vascularized bone graft spare parts have been shown to reduce the risk of subsequent fracture, provide more rapid bone union, and have the potential to remodel under physiologic load.[9-10] Composite vascularized grafts provide concomitant coverage of soft tissues and bone defects of the hand or the wrist.[11-12] Metacarpal and phalangeal (alone or composite) defects can be reconstructed with pedicled vascularized bone grafts spare parts from the metacarpals[13-14] with or without the combination of skin flaps.[3, 15,16] Kessler[17] used a one stage procedure whereby the middle finger remnant was mobilized for restoring the length of thumb and thus avoided distant donor morbidity and further procedures. An island pedicle flap of a non-functional digit was utilized by Peacock[18] to reconstruct composite tissue loss of hand.

Panagiotis,[19] used Loda's modified technique[20] for the reconstruction of thumb from an osteo-cutaneous flap of the second metacarpal. In our study we utilized a flap from the 2nd metacarpal and a filleted index finger flap separately in our case of tenosynovitis of index finger and osteomyelitis of first metacarpal. It was justified, as the presence of the stiff functionally useless finger was an obstacle to hand function but served as an excellent donor site. Furthermore, first web space was actually deepened due to this transposition and the wound was covered with a fillet flap from the index finger.

Barry[21]described use of a modified osteo-cutaneous digital fillet flap made from wounded index finger for the coverage of thumb defects. He obtained osseous union at two months postoperatively with good results. We reconstructed four segmental first metacarpal defects with osteo-cutaneous index digital fillet flap having phalangeal elements with interphalangeal joints fused with good results.

Nathan[22] utilized a single useless digit to reconstruct the soft tissues and osseous integrity in a fire arm patient and achieved excellent cosmetic and functional outcome. In two of our patients we opted for a "vascularized bone graft spare parts reconstruction" in which a single non-salvageable but perfused index digit provided two composite osteo-cutaneous vascularized tissue transfers based on each digital artery. The osteo-cutaneous pedicled flap of digital radial artery was used as a bridge for the first metacarpal defect and flap of on ulnar artery of the digit was used to fill the defect in third metacarpal. Good hand function and cosmesis was obtained.

In our two cases where the osteo-cutaneous index digital fillet with retained phalangeal elements and fused interphalangeal joints were utilized to fill the intercalated defects of first metacarpal there were extensive large soft tissue defects over hand and wrist dorsum. At second stage of operation de-dermization of the osteo-cutaneous flap was done to convert into osseo-fascial pedicle flaps followed by abdominal pedicle flap coverage. The abdominal flap was detached after three weeks and inset. Excellent wound coverage was obtained.

Attempting to salvage functionless digits would require complex surgery involving autograft from iliaic crest, tendon graft, flap and additional tendon transfers. The results were expected to be stiff and nonfunctional fingers with higher chances of infection and non-union. Furthermore, the poor socioeconomic conditions of the patients would not permit them for repeated surgeries and prolonged absence from job.

Our treatment of utilizing the injured finger for single or multiple grafts in one stage reconstruction had low donor site morbidity with early restoration of hand functions. Although some alternative surgical procedures could have preserved the digits, we feel that the treatments selected for our patients were both tailored to their needs and justified by the final outcome.[23-25]

In summary, a diversity of treatment choices is available in the management of intercalated metacarpal defects of injured hands including conventional grafts or vascularized tissue (local or free transfers). Digital vascularized bone graft spare part use offers one-stage reconstruction with minimal donor site morbidity. The

patients were able to resume their jobs as early as six months after injury.

Our study had a small sample size. We therefore recommend studies with larger sample size and longer follow up to confirm the usefulness of our technique in managing complex hand injuries.

CONCLUSION

Severely damaged and complex hand injuries treated with vascularized bone graft spare parts technique had good radiological and functional outcome. We, therefore recommend that vascularized bone graft pedicle spare parts of a severely injured hand should be innovated as a possible source for one stage reconstruction of the hand. However, the skill of the reconstructive hand surgeon is necessary to utilize the useless tissue for reconstruction without compromising the donor or recipient site.

Conflict of Interests: None
Grants/Funding: None

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Authorship and contribution Declaration

- **Muhammad Amin Cheema**, Conception and design of the study, acquisition of data, Drafted the manuscript, interpreted the data,
- **Haider Amin Cheema**, Revised the manuscript critically for important intellectual content
- **Hamza Bashir**, Final approval of the version for publication