Functional outcome following excision of giant cell tumour of the distal radius and reconstruction by autologous non-vascularized osteoarticular fibula graft

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Abstract

Purpose: Giant cell tumour (GCT) of the bone is a benign but locally aggressive tumour, commonly occurs at the metaphyseal–epiphyseal junction of the distal femur, proximal tibia, and distal radius. For Campanacci grade II and III lesions of the distal radius and in cases of recurrence, we usually carry out wide resection and reconstruction. There are numerous publications on the treatment of GCT of the distal radius. Still, reports on the functional outcome using non-vascularized fibular graft arthroplasty without fusion remain limited.

Method: We reviewed patients who underwent wide resection and non-vascularized fibular graft arthroplasty from 2007 to May 2014. The assessment was done with Musculoskeletal Tumour Society Score (MSTS), Toronto Extremities Scoring System (TESS) and Disability of the Arm, Shoulder and Hand (DASH) scores. We also reviewed the radiographic results.

Results: Fifteen patients were recruited, of whom 10 cases used ipsilateral fibular graft and five used contralateral non-vascularized fibular graft. The average duration of follow up was 6 years (3.25–9.92 years). The average grip strength was 48.1% compared to the non-operated hand. The average MSTS score was 78.4%, TESS score was 84%, and DASH score was 25.2. The average time to radiological union was 12.5 weeks. 64% (29–78%) of the range of movement is preserved compared to the normal side. The complication rate was 20%.

Conclusion: Fibula autograft arthroplasty is a feasible method of reconstruction after distal radius resection with good functional outcomes.

Keywords
giant cell tumour, reconstruction, autograft arthroplasty, functional outcome

Introduction

Giant Cell Tumour (GCT) of the bone is a locally aggressive lesion with a high tendency for local recurrence. The distal radius is the third most common site for GCT occurrence and it also has the highest incidence of recurrence. These tumours are graded via the Campanacci grading system.
Grade I, the tumour, is confined within the bone; Grade II is where the bone is expanded, and Grade III is where the tumour has broken through the cortex with soft tissue extension. Therefore, Campanacci Grade II and III tumours in this region are generally treated with wide local resection and reconstruction. The reconstruction options described in the literature include vascularized and non-vascularized osteoarticular fibular arthroplasty or arthrodesis, use of allograft or osteoarticular allograft, the fusion of wrist with iliac crest autograft and transposition of the ulna with the fusion of wrist. We describe our series of patients treated with non-vascularized fibular graft arthroplasty.

Material and methods

This is a retrospective review of patients who underwent wide resection of distal radius and reconstruction with non-vascularized fibula graft arthroplasty from 2007 till 2014, with a minimum follow-up of three years. We recruited only patients with primary tumour at their first presentation for this study, excluding patients with recurrent disease. We
identified suitable patients from our orthopaedic oncology database. They were then assessed in the clinic by the principal investigator during follow up where the following parameters were measured and compared to the unaffected contralateral limb; the range of motion (measured with a goniometer) and grip strength (measured with Jamar hydraulic dynamometer; model no. 5030J1). All measurements were made in triplicates, and the average was taken. Functional scores were evaluated with modified Musculoskeletal Tumour Society Score (MSTS), Toronto Extremities Scoring System (TESS) and Disability of the Arm, Shoulder and Hand (DASH) scores. Serial radiographs taken during follow-up were assessed by the investigators and reported by a radiologist to determine the time of union and radiological progress of replacement. Union is defined as bridging callus on at least three cortices on Anterior-Posterior and Lateral views of plain radiographs. Subluxations, dislocations and radiocarpal joint narrowing were measured three years post-surgery. We obtained ethical approval from the institutional review board and took informed consent from all subjects involved in this study.

**Surgical Procedure**

The same operating team performed the surgical procedure for every case. A pneumatic tourniquet is applied to both the operated limb and the donor’s leg. In most cases, the ipsilateral fibula was harvested but, in some cases, the contralateral fibula was used based on the surgeon preference after discussing with the patient. The approach used for the distal radius was either an isolated volar or combined volar and dorsal approach depending on the dorsal extension of the tumour into soft tissue.

The distal radius and the surrounding soft tissue were carefully dissected without spillage or breakage into the tumour. We routinely sacrifice pronator quadratus, as in the majority of cases, the tumour breaches the volar cortex of the distal radius and is contained by this muscle. The distal margin of resection was the radiocarpal joint and extrinsic radiocarpal ligaments, and the proximal margin was 3 cm–5 cm of normal bone (Figure 1). The tumour did not breach the radiocarpal joint in any of the cases.

![Figure 2. Postoperative radiograph at six weeks (Kirschner wire removed).](image-url)
As for harvesting the proximal fibula graft, the incision is made laterally over the fibula. The fibula is approached posteriorly to peroneal longus muscle. The common peroneal nerve is routinely identified and lifted anteriorly together with peroneal longus muscles. The fibula graft length is based on resection length. It is harvested with a small stump of fibula collateral ligament. The remnant of the lateral collateral ligament is anchored down to the soft tissue.

### Table 1. Summary of demography, approach and radiological findings.

| Patient no | Age | Gender | Follow up (months) | Campanacci | Fibula graft | Length, cm | Approach | Union (days) | Subluxation | Fibula carpal joint narrowing |
|------------|-----|--------|-------------------|-------------|--------------|------------|----------|--------------|-------------|-----------------------------|
| 1          | 51  | Male   | 61                | Ipsilateral | 7.5          | Combined   | 43       | <0.5 cm      | No change   |                             |
| 2          | 32  | Female | 97                | Ipsilateral | 5            | Volar      | 120      | nil          | 2–4 mm      |                             |
| 3          | 34  | Female | 61                | Ipsilateral | 7            | Combined   | 132      | <0.5 cm      | <2 mm       |                             |
| 4          | 54  | Female | 61                | Ipsilateral | 12           | Combined   | 40       | nil          | No change   |                             |
| 5          | 38  | Female | 99                | Ipsilateral | 8            | Combined   | 64       | <0.5 cm      | <2 mm       |                             |
| 6          | 29  | Female | 62                | Ipsilateral | 7.5          | Volar      | 92       | nil          | No change   |                             |
| 7          | 38  | Female | 119               | Ipsilateral | 6            | Combined   | 46       | >1 cm        | <2 mm       |                             |
| 8          | 29  | Female | 58                | Ipsilateral | 11           | Volar      | 56       | nil          | <2 mm       |                             |
| 9          | 24  | Female | 82                | Ipsilateral | 6.3          | Volar      | 70       | <0.5 cm      | <2 mm       |                             |
| 10         | 34  | Male   | 30                | Ipsilateral | 9.5          | Combined   | 39       | <0.5 cm      | <2 mm       |                             |
| 11         | 46  | Male   | 60                | Ipsilateral | 8            | Combined   | Infected non-union | <0.5 cm  | <2 mm |
| 12         | 56  | Male   | 112               | Ipsilateral | 7            | Volar      | 168      | <0.5 cm      | <2 mm       |                             |
| 13         | 38  | Female | 106               | Ipsilateral | 10           | Combined   | 195      | <0.5 cm      | <2 mm       |                             |
| 14         | 56  | Female | 39                | Ipsilateral | 7            | Volar      | 68       | >1 cm        | >4 mm       |                             |
| 15         | 55  | Male   | 39                | Ipsilateral | 6.5          | Volar      | 46       | >1 cm        | >4 mm       |                             |

### Figure 3. Shows and example of fibula carpal joint subluxation.
| Patient no | MSTS (%) | DASH | TESS (%) | Grip strength (% of normal) | Flexion (% of normal) | Extension (% of normal) | Radial Deviation (% of normal) | Ulnar deviation (% of normal) | Pronation (% of normal) | Supination (% of normal) | Complications |
|-----------|----------|------|----------|-----------------------------|----------------------|------------------------|-------------------------------|---------------------------|-----------------------|------------------------|-----------------|
| 1         | 70       | 12   | 91.7     | 50                          | 87.5                 | 37.5                   | 66.7                          | 50                        | 33.3                  | 88.9                   | None            |
| 2         | 80       | 27   | 86.9     | 33                          | 68.8                 | 0                      | 50                            | 50                        | 50                    | 100                    | None            |
| 3         | 80       | 54   | 80.7     | 100                         | 75                   | 37.5                   | 66.7                          | 33.3                      | 16.7                  | 16.7                   | None            |
| 4         | 87       | 23   | 78.6     | 44                          | 66.7                 | 44.4                   | 88.9                          | 33.3                      | 83.3                  | 80.9                   | None            |
| 5         | 93       | 18   | 78.6     | 52                          | 66.7                 | 66.7                   | 30                            | 20                        | 100                   | 100                    | None            |
| 6         | 90       | 11   | 92.4     | 72                          | 100                  | 88.9                   | 83.3                          | 83.3                      | 80.9                  | 88.9                   | Big toe drop    |
| 7         | 67       | 42   | 72.4     | 36                          | 16.7                 | 33.3                   | 50                            | 50                        | 16.7                  | 33.3                   | Bony recurrence with Graft fracture |
| 8         | 83       | 27   | 83.4     | 72                          | 66.7                 | 42.9                   | 50                            | 100                       | 100                   | 77.8                   | None            |
| 9         | 87       | 20   | 91       | 62                          | 43.8                 | 50                     | 66.7                          | 85.7                      | 33.3                  | 100                    | None            |
| 10        | 83       | 29   | 84.1     | 41                          | 50                   | 50                     | 33.3                          | 33.3                      | 50                    | 50                     | None            |
| 11        | 30       | 59   | 57.9     | 30                          | 0                    | 0                      | 44.4                          | 33.3                      | 50                    | 0                      | Infected Non-union |
| 12        | 93       | 10   | 95.2     | 55                          | 0–40 (44.4)           | 22.2                   | 22.2                          | 11.1                      | 0                     | 100                    | None            |
| 13        | 80       | 59   | 79.9     | 39                          | 0                    | 0                      | 44.4                          | 33.3                      | 0                     | 100                    | None            |
| 14        | 76.7     | 18   | 89.6     | 8                           | 0–45 (56.3)           | 0                      | 33.3                          | 0                         | 100                   | 100                    | None            |
| 15        | 76.7     | 19   | 84.8     | 25                          | 0–40 (44.4)           | 37.5                   | 0                             | 44.4                      | 50                    | 66.7                   | None            |

*Percentage loss is in relation to the contralateral limb.
Table 3. Showing correlation between gender, age, race, pathology side, fibula graft side, fibula graft length, approaches and radiological assessment (ISOLS) and patient satisfaction assessment (DASH, TESS and MSTS) with p-value and n from top to bottom.

|                         | Time to remodelling | Degree of resorption | Degree of subluxation | Subchondral bone changes | Joint Space Narrowing | Average Hand Function | MSTS | DASH | TESS |
|-------------------------|---------------------|----------------------|-----------------------|--------------------------|-----------------------|-----------------------|------|------|------|
| Gender                  | 0.543               | 0.263                | 0.251                 | 0.567                    | 0.850                 | 0.062                 | 0.176| 0.920| 0.694|
| Age                     | 0.350               | 0.416                | 0.037                 | 0.147                    | 0.334                 | 0.051                 | 0.495| 0.549| 0.261|
| Race                    | 0.204               | 0.333                | 0.168                 | 0.652                    | 0.219                 | 0.458                 | 0.456| 0.196| 0.230|
| Pathology Hand (Right Side) | 0.829            | 0.967                | 1.000                 | 0.114                    | 0.566                 | 0.493                 | 0.978| 0.452| 0.898|
| Fibula Graft Side (Ipsilateral) | 0.757           | 0.375                | 0.574                 | 1.000                    | 0.337                 | 0.373                 | 0.067| 0.033| 0.029|
| Fibula Length           | 0.784               | 0.302                | 0.218                 | 0.183                    | 0.107                 | 0.941                 | 0.676| 0.711| 0.936|
| Approaches              | 0.536               | 0.113                | 0.595                 | 0.114                    | 0.082                 | 0.189                 | 0.220| 0.141| 0.353|
around the tibia to prevent lateral collateral ligament laxity of the knee joint.

The fibula graft is routinely trimmed 2 mm–3 mm shorter than the resected bone and inserted into the resection bed and rotated until it is positioned comfortably; the fibula carpal joints were stable and did not subluxate. All patients were purposely given a positive ulnar variance by shortening the donor fibula to allow better fibula carpal joint

Figure 4. Shows series of radiograph for patient 7 (a) Immediate postoperative radiographs. (b) Well incorporated fibula graft (non-vascularized). (c) Bony recurrence within the graft with subluxation of wrist joint. (d) Revised with vascularized fibula graft. (e) Peri-prosthetic fracture of the vascularized fibula graft. (f) Union of the vascularized fibula graft after removal of plate and splinting. The close-up radiograph shows subluxation of the wrist.
stability. The rotational alignment was marked with diathermy on both proximal fibula and proximal radius to determine the alignment for plating. The fibula is then plated to the radius with a 6-hole narrow Dynamic Compression Plate (DCP). A periosteal sleeve is kept from the resected bone and advanced over the host bone fibula junction during the plating. The remnant fibula collateral ligament is repaired to the carpal ligament. K wires are used to stabilise the fibula ulna joint and the fibula carpal joint. These wires are kept in situ for six weeks. There is no soft tissue reconstruction done for the distal

Figure 4. Continued.
The tourniquet is then released, and haemostasis secured. Finally, a single surgical drain is inserted, and the wounds are closed with interrupted sutures.

**Postoperative protocol**

A thermoplastic ulna gutter splint is applied in neutral position and kept for six weeks. Sutures are removed at two weeks, and the Kirschner wires at six weeks (Figure 2). After which, patients continued to wear the splint for another six weeks as night splints and physiotherapy is initiated. Regular usage of the arm is allowed after three months, and patients are advised against heavy lifting (anything more than 10 kg) and doing strenuous activities.

### Results

A total of 15 patients with complete records underwent wide resection of the distal radius with non-vascularized fibular graft arthroplasty (Table 1). The mean age was 40.9 years (24–56; SD ± 6.143). The majority of the patients were female (67%). 60% of the cases involved the dominant hand. 73.3% were Campanacci grade II, 27% were Campanacci grade III, and there were no cases of Grade I tumours. The average duration of follow up was six years (3.25–9.92 years). The fibular graft was taken from the ipsilateral site in 66.7% and the contralateral site in 33.3% of the patients.

The mean resection length of distal radius was 7.89 cm (range: 5–12 cm; SD ± 1.07). In seven cases, the volar approach was used in isolation, and in eight patients, a combined volar and dorsal approach was used.

The fibula carpal joint was reduced in 27% of subjects (assessed both radiologically and clinically), while 53% had less than 0.5 cm subluxation (Figure 3) and 20% had ≥0.5 cm subluxation of the joint. There were no dislocations of the joint. The fibula ulna joint was intact in all 15 cases. 60% had <2 mm joint space narrowing of the fibula carpal joint. Union rate was 93.3% (n = 14) and the average time to union was at 12.5 weeks (range: 5.6–27.9; SD + 7.2).

The average grip strength was 48.07% (range: 9–99%; SD ± 12.43) compared to the opposite hand. The average range of movements was 67° (0°–100°) for forearm supination, 45° (0°–90°) for forearm pronation, 47° (0°–90°) for wrist flexion, 27° (0°–80°) for wrist extension with combined movements of 162° (80°–200°). Overall, 64% (29–78%) of the global range of motion was preserved (Table 2).

The mean MSTS score was 78.4% (range: 30–93), DASH score was 25.2 (range: 9–59) and TESS score was 83.98% (range: 57.9–95.2%). The use of ipsilateral fibula significantly gave better TESS (p = 0.029) and DASH (p = 0.033) scores but not MSTS (p = 0.067) score and did not affect the grip strength (p = 0.505) (Table 3).

We had one case of infected non-union, which was treated with debridement and external fixator followed by iliac crest bone grafting and fusion of the wrist. There was another case of graft collapse secondary to bony recurrence and subluxation of the fibula carpal joint. It was treated with a vascularized fibula graft from the opposite side. However, this graft eventually fractured distal to the plate. It was

| Authors                   | No | Type of procedure       | Diagnosis                          | Method of fixation            | Follow up (years) |
|---------------------------|----|-------------------------|------------------------------------|--------------------------------|------------------|
| Vander Griend et al.       | 8  | Arthroplasty (2), Arthrodesis (6) | GCT                               | Plate                           | 5.1 (2–9)       |
| Maruthainar et al.         | 13 | Arthroplasty             | GCT (10), Osteosarcoma (1), Chondrosarcoma (1), Ewing’s sarcoma (1) | Plate + Bone Graft             | 4.2 (2.2–7.5)   |
| Saikia et al.              | 24 | Arthroplasty             | GCT                               | Plate + Bone graft             | 6.6 (2–11)      |
| Lackman et al.             | 12 | Arthroplasty             | GCT                               | Plate                           | 8 (3–14)        |
| Murray et al.              | 18 | Arthroplasty (3), Arthrodesis (15) | GCT                              | IM rod with screws (3), Plate (15) | 7.1 (2–24.2)   |
| Salenius et al.            | 6  | Resection arthroplasty   | Chondrosarcoma (1), GCT (3), Haemangioma (2) | Screws (3), Plate (3)          | 5 (2–12)        |
| Aithal et al.              | 30 | Arthroplasty             | GCT                               | Screws (3), Rush nail (1), Plate (26) | 8.5 (1.5–25.5) |
| Asavamongkolkul            | 7  | Arthroplasty             | GCT                               | Plate                           | 5.8 (4.2–8)     |
| Bassiony et al.            | 10 | Arthroplasty             | GCT                               | Plate + Bone Graft             | 3.9 (2.5–5)     |
| Chadha et al.              | 9  | Arthroplasty             | GCT                               | Plate                           | 4.7 (3.2–5.75)  |
| Saini et al.               | 12 | Arthroplasty             | GCT                               | Plate + Bone Graft             | 5.8 (3.7–8.2)   |
| This study                 | 15 | Arthroplasty             | GCT                               | Plate + Bone Graft             | 6.0 (3.25–9.92) |

**Table 4. Literature review of other published series.**

| Authors                        | No | Type of procedure | Diagnosis                              | Method of fixation | Follow up (years) |
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| This study                      | 15 | Arthroplasty       | GCT                                    | Plate + Bone Graft | 6.0 (3.25–9.92) |

The mean MSTS score was 78.4% (range: 30–93), DASH score was 25.2 (range: 9–59) and TESS score was 83.98% (range: 57.9–95.2%). The use of ipsilateral fibula significantly gave better TESS (p = 0.029) and DASH (p = 0.033) scores but not MSTS (p = 0.067) score and did not affect the grip strength (p = 0.505) (Table 3).

We had one case of infected non-union, which was treated with debridement and external fixator followed by iliac crest bone grafting and fusion of the wrist. There was another case of graft collapse secondary to bony recurrence and subluxation of the fibula carpal joint. It was treated with a vascularized fibula graft from the opposite side. However, this graft eventually fractured distal to the plate. It was
treated with plate removal and splinting. It eventually united with slight bowing and subluxation of the fibula carpal joint (Figure 4). One case of iatrogenic common peroneal nerve injury resulted in numbness and deep peroneal nerve distribution and inability to dorsiflex the big toe. It did not improve throughout the study. There was only one case of bony local recurrence (as noted above) and no cases of soft tissue recurrences.

These complications did not have a significant bearing on MSTS ($p = 0.102$) and DASH ($p = 0.115$) scores and grip strength ($p = 0.551$), but it significantly affected the TESS scores ($p = 0.002$). Figure 5 shows radiographs of patient 6 from presentation till the recent radiograph taken five years after the index surgery and the recent functional pictures.

**Discussion**

The giant cell tumour of the bone is a locally aggressive lesion with a local recurrence rate of 0–65% depending on the grade of the tumour (Campanacci) and chosen treatment method. Campanacci grade II and III tumours are generally treated with wide resection and replacement with or without wrist fusion (arthroplasty or arthrodesis) as the local recurrence rate for an intralesional procedure is high.

**Table 4** shows a summary of other published articles and their method of reconstruction. The advantage of utilising a non-vascularized fibula autograft is that the surgery is not technically demanding as it does not involve microvascular anastomosis. There is low donor site morbidity and has
### Table 5. Comparing publications with a large series in the literature with this study.

| Authors          | Complications                          | Results/MSTS     | ROM (°)                      | Grip strength | Secondary procedure |
|------------------|----------------------------------------|------------------|-----------------------------|---------------|---------------------|
| Vander Griend et al.⁴ | 87.5%                                   | NA               | NA                          | NA            | 5 (62.5%)           |
|                  | - Subluxation (2)                       |                  |                             |               |                     |
|                  | - Graft fracture (3)                    |                  |                             |               |                     |
|                  | - Non-union (2)                         |                  |                             |               |                     |
| Maruthainar et al.¹² | 54%                                     | NA               | PF 16 (5–30)                | 57%           | 3 (23%)             |
|                  | - Subluxation (4)                       |                  | DF 22 (0–60)               |               |                     |
|                  | - Recurrent GCT (2)                     |                  | Pr 66 (30–90)              |               |                     |
|                  | - Amputation (1)                        |                  | Su 52 (0–90)               |               |                     |
| Salkia et al.¹⁵   | 62.5%                                   | 6 excellent, 14 good, 4 fair | DF 50, PF 38, Su 52, Pr 46, (63%; 52–78) | 67% (58–74) | 2 (0.1%)            |
|                  | - Subluxation (10)                      |                  |                             |               |                     |
|                  | - Recurrence (1)                        |                  |                             |               |                     |
|                  | - Infection (1)                         |                  |                             |               |                     |
|                  | - Graft fracture (1)                    |                  |                             |               |                     |
|                  | - Wrist arthrosis (2)                   |                  |                             |               |                     |
| Lackman et al.¹⁶  | 58%                                     | 6 excellent, 4 good, 2 fair | PF 21 (5–45) | 49% (24–88%) | 4 (33%)             |
|                  | - Non-union (2)                         |                  |                             |               |                     |
|                  | - Recurrence (1)                        |                  |                             |               |                     |
|                  | - Graft fracture (3)                    |                  |                             |               |                     |
|                  | - Subluxation (1)                       |                  |                             |               |                     |
| Murray et al.¹⁷   | 77%                                     | 8 excellent, 8 good, 1 satisfactory | DF 40% (0–85) | 40% (2–70%) | 12 (67%)             |
|                  | - Recurrence (5)                        |                  |                             |               |                     |
|                  | - Pulmonary metastasis (1)              |                  |                             |               |                     |
|                  | - Non-union (5)                         |                  |                             |               |                     |
|                  | - Graft fracture (3)                    |                  |                             |               |                     |
| Salenius et al.¹⁸ | 0%–None                                 | All good         | <20% reduced               | Manual work at 6 months | None               |
| Aithal et al.¹⁹   | 70%                                     | 11 good, 7 fair, 2 poor (excluding recurrences) | >65% in 7, 35–64% in 7, <34% in 3, 35–64% in 7, <34% in 2 | >65% in 11, | 6 (20%)             |
|                  | - Recurrence (10)                       |                  |                             |               |                     |
|                  | - Amputation (4)                        |                  |                             |               |                     |
|                  | - Non-union (3)                         |                  |                             |               |                     |
|                  | - Infection (1)                         |                  |                             |               |                     |
|                  | - Subluxation (3)                       |                  |                             |               |                     |
| Asavamongkolkul et al.¹⁰ | 29%                                    | 6 excellent, 1 good | DF 45, PF 38, Su 80, Pr 42 (73.7%) | 69% | None               |
|                  | - Radiocarpal arthritis (2)             |                  |                             |               |                     |
| Bassiony et al.²¹  | 30%                                     | NA               | 100.5(60–125)               | NA            | 3 (30%)             |
|                  | - Non-union (1)                         |                  |                             |               |                     |
|                  | - Graft desorption (1)                  |                  |                             |               |                     |
|                  | - Recurrence (1)                        |                  |                             |               |                     |
| Chadha et al.²⁴   | 77%                                     | NA               | DF 40,                      | 50%           | 4 (44%)             |
|                  | - Recurrence (1)                        |                  |                             |               |                     |
|                  | - Graft fracture (2)                    |                  |                             |               |                     |
|                  | - Radial artery injury (1)              |                  |                             |               |                     |
|                  | - Subluxation (1)                       |                  |                             |               |                     |
|                  | - Tourniquet plasty (1)                 |                  |                             |               |                     |
| Saini et al.²⁵    | 50%                                     | 5 excellent, 4 good, 3 satisfactory | DF 31, PF 42, Su 52, Pr 37 | 71% (42–86%) | 6 (50%)             |
|                  | - Subluxation (3)                       |                  |                             |               |                     |
|                  | - Non-union (2)                         |                  |                             |               |                     |
|                  | - Recurrence (1)                        |                  |                             |               |                     |
| This study        | 20%                                     | 78.4 (30–93.3) | DF27, PF47, Su67           | 48% (9–99%) | 3 (13%)             |
|                  | - Subluxation (11)                      |                  |                             |               |                     |
|                  | - Infected non-union (1)                |                  |                             |               |                     |
|                  | - Graft fracture (1)                    |                  |                             |               |                     |
|                  | - Graft collapse (1)                    |                  |                             |               |                     |

DF: Dorsi flexion; PF: Palmar flexion; Su: Supination; Pr: Pronation; NA: Not available.
encouraging functional results. The advantage of arthroplasty over arthodesis is that it preserves some degree of wrist flexion and extension. Therefore, it is the preferred method of reconstruction at our centre.

We prefer the volar surgical approach in resecting these tumours. Still, in almost half the cases, a combined volar and dorsal approach was used to ease resection as there was dorsal extension of the tumours. A combined dorsal approach allows us to release the dorsal extensor tendons from the dorsal compartments via direct visualisation and avoids spillage of the tumour due to tumour breakage.

We used ipsilateral fibula in two-thirds of the cases in this series and contralateral fibula in one-third of the patients. Although it is more convenient for two operating teams to operate on opposite sides of the patient, we prefer harvesting the ipsilateral fibula. This is because we realised that the ipsilateral fibula is more compatible anatomically than the contralateral fibula in terms of the fibula carpal joint’s stability. Furthermore, we have shown that patients with ipsilateral fibula have a better functional score (DASH and TESS scores).

There were no cases of fibula carpal dislocations. Despite 73% of the subjects having some degree of subluxation of the joint and 60% of the subjects had < 2 mm joint space narrowing noted on the last follow up, the functional outcome of our patients is similar to other studies in the literature. Our mean MSTS and TESS scores were 78.4% and 83.98%, respectively, which is comparable to other studies using similar reconstruction technique and other forms of reconstruction (Table 5). We also used the DASH score for assessment, which was not routinely done in most publications. The DASH score of this study was 25.2, which is within the acceptable range. The fibula carpal subluxations can be prevented by shortening the transplanted fibula slightly shorter giving rise to a slight ulna plus to provide more stability to the reconstructed joint, ensuring strict adherence to splinting for 6 weeks, followed by another 6 weeks of using the splint as a night splint, while the patient is undergoing physiotherapy.

Salunke et al. reported 25 cases, and Puri et al. reported 14 patients with GCT distal radius treated with resection and reconstruction with ulna transposition and fusion. Their MSTS scores were 80% and 87%, respectively. These scores are similar to our study, but their reconstruction form sacrificed the flexion and extension movement of the wrist. These authors cited the advantage of better union rates at the host bone graft junction (6.5 months and 4.9 months, respectively) as their graft was vascularized. However, the host graft junction’s union rate in our study was shorter despite utilising a non-vascularized graft. Our study’s union rate is 93.3% (n = 14), and the average duration for the radiological union was 12.5 weeks. The earliest radiological union was documented at 39 days. This may be due to the periosteal sleeve advanced to cover the host bone and graft junction. It may induce bone healing. There was only one case of non-union due to infection. Liu S et al. reported a mean union time for non-vascularized fibula graft of 30.5 weeks, and Humail SM reported a mean radiological union at 16 weeks.

The range of movement and grip strength documented in our study is similar to other reported series (Table 5). Furthermore, the rate of secondary procedures in our series was 13%, which is considered low compared to the other published studies (Table 5).

There is a risk of chronic leg pain, laxity of the collateral ligament at the knee, palsy of the peroneal nerve and dyseaesthesia of the calf associated with harvesting of the proximal fibula graft. In this series, we encountered two complications related to the operated site and one related to the donor site, amounting to a 20% overall complication rate. For the donor site morbidity, the patient had a loss of sensation over the common peroneal nerve distribution with a big toe drop even after 62 months of follow up. The complication rates reported in the literature vary from 0 to 87.5%. Therefore, our complication rate is considered low for non-vascularized fibular graft arthroplasty without fusion (Table 5). We have one case of bony recurrence within the transplanted fibula. We postulate that it may be due to transplantation of the tumour cell to the graft during the surgery.

There has been development in using a 3D printed prosthesis to replace native bone. To date, there are only some isolated case reports, and one such case is reported by V Kuptniratsaikul et al. The advantage of such an implant is that it is custom made to fit the size and morphology of the resected segment and avoids donor site morbidity. But I suspect it will have all the complications associated with metal prostheses, such as infection and implant failure. What the future holds for such implants remains to be seen.

From this study, the author recommends using the ipsilateral fibula to advance the periosteal sleeve over the host bone junction and graft bone and to put the graft in a slight ulna plus position to have a more stable fibula carpal joint.

This study has its limitations in terms of the small number of recruited patients, attributed to this condition’s low prevalence rate. As we are using non-vascularized grafts, longer lengths are associated with higher complications, as described by Krieg and Hefti. They reported a 15% complication rate of fatigue fractures and the incidence is higher when a graft 12 cm and longer was used.

**Conclusion**

Non-vascularized proximal fibula autograft arthroplasty without fusion is a feasible reconstruction option after distal radius resection for patients with giant cell tumours. It has a reasonable union rate and preserves the wrist joint while giving good functional outcomes. Furthermore, fusion is an
available option if the arthroplasty fails or when the subject develops symptomatic osteoarthritis.

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References
1. Eckardt JJ and Grogan TJ. Giant cell tumour of bone. Clin Orthop Relat Res 1986; 204: 45–58.
2. Dahlin DC, Cupps RE and Johnson EW, Jr. Giant cell tumour: a study of 195 cases. Cancer 1970; 25: 1061–1070.
3. Goldenberg RR, Campbell CJ and Bonfiglio M. Giant-cell tumour of bone. An analysis two hundred and eighty cases. J Bone Joint Surg Am 1970; 52: 619–664.
4. Campanacci M. Giant cell tumor. In: Campanacci M (ed) Bone and Soft Tissue Tumors. 2nd ed. New York: Springer-Verlag, 1999, pp. 99–142.
5. Vander Griend RA and Funderburk CH. The treatment of giant-cell tumours of distal part of the radius. J Bone Joint Surg Am 1993; 75: 899–908.
6. Carencesale PG. Tumours. In: Creshaw AH (ed) Campbell’s Operative Orthopaedics. 7th ed. St Louis: Mosby, 1987, pp. 738–739.
7. Van Demark RE, Jr and Van Demark RE, Sr. Non-vascularized fibular autograft to treat recurrent giant cell tumour of the distal radius. J Hand Surg Am 1988; 13: 671–675.
8. Pho RW. Malignant giant-cell tumour of distal end of the radius treated by a free vascularized fibular transplant. J Bone Joint Surg Am 1981; 63: 877–884.
9. Ihara K, Doi K, Sakai K, et al. Vascularized fibular graft after excision of giant cell tumour of the distal radius. A case report. Clin Orthop Relat Res 1999; 359: 189–196.
10. Makin HJ. Allograft replacement for the management of skeletal defects incurred in tumour surgery or trauma. In: Chao EY and Ivins JC (eds) Tumour Prostheses for Bone and Joint Reconstruction. New York: Thieme Stratton, 1983, pp. 23–24.
11. Bianchi G, Donati D, Staals EL, et al. Osteoarticular allograft reconstruction of the distal radius after bone tumour resection. J Hand Surg Br 2005; 30: 369–373.
12. Dhammi IK, Jain AK, Maheshwari AV, et al. Giant cell tumours of lower end of the radius: problems and solutions. Indian J Orthop 2005; 39: 201–205.
13. Salunke AA, Shah J, Warikoo V, et al. Giant cell tumour of distal radius treated with ulnar translocation and wrist arthrodesis: What are the functional outcomes? J Orthopaedic Surg 2017; 25(1): 230499016684972.
14. Puri A, Gulia A, Agarwal MG, et al. Ulnar translocation after excision of a Campanacci grade-3 giant-cell tumour of the distal radius: an effective method of reconstruction. J Bone Joint Surg Br 2010; 92(6): 875–879.
15. Klenke FM, Wenger DE, Inwards CY, et al. Giant cell tumour of bone: risk factors for recurrence. Clin Orthopaedics Relat Res 2011; 469(2): 591–599.
16. Maruthainar N, Zambakis G, Harper G, et al. Functional outcome following excision of the tumours of the distal radius and reconstruction by autologous non-vascularized osteoarticular fibula grafting. J Hand Surg Br 2002; 27: 171–174.
17. Harness NG and Mankin HJ. Giant-cell tumour of the distal forearm. J Hand Surg Am 2004; 29: 188–193.
18. Cheng CY, Shih HN, Hsu KY, et al. Treatment of giant cell tumour of the distal radius. Clin Orthop Relat Res 2001; 383: 221–228.
19. Saikia KC, Borghain M, Bhuyan SK, et al. Resection-reconstruction arthroplasty for giant cell tumour of distal radius. Indian J Orthop 2010; 44: 327–332.
20. Lackman RD, McDonald DJ, Beckenbaugh RD, et al. Fibular reconstruction for giant cell tumour of the distal radius. Clin Orthop Relat Res 1987; 218: 232–238.
21. Murray JA and Schlaffy B. Giant-cell tumours in the distal end of the radius. Treatment by resection and fibular autograft interpositional arthrodesis. J Bone Joint Surg Am 1986; 68(5): 687–694.
22. Salenius P, Santavirta S, Kiviluoto O, et al. Application of free autogenous fibular graft in the treatment of aggressive bone tumours of the distal end of the radius. Arch Orthop Trauma Surg 1981; 98(4): 285–287.
23. Aithal VK and Bhaskaranand K. Reconstruction of the distal radius by fibula following excision of giant cell tumour. Int Orthop 2003; 27(2): 110–113.
24. Asavamongkolkul W, Waikakul S, Phimolsamit R, et al. Functional outcome following excision of a tumour and reconstruction of the distal radius. Int Orthop 2009; 33(1): 203–209.
25. Bassocny AA. Giant cell tumor of the distal radius: wide resection and reconstruction by non-vascularized proximal fibular autograft. Ann Acad Med Singapore 2009; 38(10): 900–904.
26. Campanacci M. Giant-cell tumour and chondrosarcomas: grading, treatment and results (studies of 209 and 131 cases). Recent Results Cancer Res 1976; 54: 257–261.
27. Harris WR and Lehmann EC. Recurrent giant-cell tumour after en bloc excision of the distal radius and fibular autograft replacement. J Bone Joint Surg Br 1983; 65(5): 618–620.
28. Saint R, Bali K, Bachhal V, et al. En bloc excision and autogenous fibular reconstruction for aggressive giant cell tumour of distal radius: a report of 12 cases and review of literature. J Orthopaedic Surg Res 2011; 6(1): 14.
29. Liu S, Tao S, Tan J, et al. Long-term follow-up of fibular graft for the reconstruction of bone defects. *Medicine* 2018; 97(40): e12605.

30. Humail SM, Ghulam MK and Zaidi IH. Reconstruction of the distal radius with non-vascularized fibular graft after resection of giant cell tumour of bone. *J Orthopaedic Surg* 2014; 22(3): 356–359.

31. Chadha M, Arora SS, Singh AP, et al. Autogenous non-vascularized fibula for treatment of giant cell tumour of distal end radius. *Arch Orthop Trauma Surg* 2010; 130(12): 1467–1473.

32. Kuptniratsaikul V, Luangjarmekorn P, Charoenlap C, et al. Anatomic 3D-printed endoprosthetic with multiligament reconstruction after en bloc resection in giant cell tumor of distal radius. *JAAOS Glob Res Rev* 2021; 5(2): e20.00178.

33. Krieg AH and Hefti F. Reconstruction with non-vascularised fibular grafts after resection of bone tumours. The Journal of bone and joint surgery. *Br Volume* 2007; 89(2): 215–221.