TECHNICAL NOTE

Post-traumatic malunion of the distal radius treated with autologous costal cartilage graft: A technical note on seven cases

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KEYWORDS
Intra-articular malunion; Distal radius fracture; Costal cartilage graft; Articular surface defect

Summary Seven cases of post-traumatic intra-articular malunion of the distal radius treated using costal cartilage graft with a minimum follow-up of 2 years are reported. Location of the articular defect was dorsal in two cases and volar in the others. The approach (dorsal or volar) depended on the main location of the defect. A costal cartilage graft harvested on the eighth rib was implanted in a trough created at the epiphysis metaphyseal junction. This trough removed the defective area on the distal radius articular surface. A plate or wire fixation was used to stabilize in place the graft. Plaster cast wear was prescribed for 3 months in the first case and for 1 month in the other cases following joint reconstruction. No complications were observed. Union was achieved in all seven cases. Graft integration and viability were evaluated with MRI and biopsy. At the longest follow-up, the functional results were excellent in the first (youngest) case (male, 22 years old) in whom motion and grasp were similar to the contralateral side. In the other cases of malunion, the patients were pain-free in daily activities with a functional wrist score of 72/100 (range, 54–82) and a DASH score of 38.3 (range, 22.5–51.7). Only the case with a septic problem failed, with pain reported at follow-up. Reconstruction of a partially destroyed articular surface using a costal graft is reliable and allows filling and resurfacing an articular cartilage void. Although costal cartilage graft is currently used in maxillofacial surgery, this is the first report in post-traumatic osteoarthritis secondary to intra-articular malunion.

Level of evidence: Level IV.
Introduction

In cases of fracture of the distal radius, reduction and anatomic fixation allow optimal reconstruction of the radial epiphysis correlated with function in patients who demand a high level of function. In cases of extra-articular malunion, treatment has been codified (analysis and treatment of deformities in the three planes), even though involvement of the distal radioulnar joint determines the prognosis [1–4]. However, in cases of intra-articular malunion, which are infrequent, the solutions remain uncertain and most often consist in partial or total arthrodesis. In cases of functional complaints (pain, stiffness), the therapeutic solutions remain disappointing because the disappearance of pain comes at the cost of the loss of mobility. We report the first series of patients (seven cases) presenting partial destruction of the radial joint surface treated with chondrocostal autografting.

Material and methods

Patients

Seven patients presenting symptomatic destruction of the distal radius were included in this prospective study: five had presented a high-energy joint fracture classified E4 in Laulau’s MEC (metaphysis, epiphysis, ulna) classification [5], and C in the AO classification (Table 1). These fractures, reduced in an emergency setting, were followed by rapid arthritic progression because of an osteocartilaginous defect. One patient presented osteoarthritis several years after injury without fracture of the distal radius and another presented probably septic scaphoradial destruction following scaphoid surgery. Of the five cases of fracture, an emergency management error occurred in three cases (non reduced dislocation in one case, non reduced joint impaction in two cases). In all these cases, the patients complained of three symptoms: moderate but continuous pain (mean VAS, 5 [range, 2–8]), functional loss in flexion—extension (mean flexion—extension, 44° [range, 20–70°], i.e., 44% of the contralateral side), and loss of wrist strength measured on the Jamar dynamometer (15 kgf [range, 4–24]). Pronosupination was preserved in all cases. The cartilage and bone defect assessed in all cases on CT slices occupied the posterior and centroposterior part in three cases. Only one volar intercalated segment instability was visible in the youngest patient, which this corresponded to an incarcerated capsular fragment and extrinsic ligaments. All of the patients were reviewed by an independent operator and functionally assessed (range of motion in flexion—extension, wrist strength, DASH score). X-ray and

<table>
<thead>
<tr>
<th>Patients</th>
<th>Initial lesion</th>
<th>Initial treatment</th>
<th>Type of malunion Substance loss</th>
<th>Complaints</th>
<th>Flexion/extension</th>
<th>Wrist strength (Jamar) (kgf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Complex joint fracture</td>
<td>Reduction + cast</td>
<td>Unreducible dislocation</td>
<td>Stiffness</td>
<td>20°</td>
<td>22</td>
</tr>
<tr>
<td>22 years</td>
<td>Dominant wrist</td>
<td></td>
<td>Dorsal deformity</td>
<td>Pain</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Intra-articular fracture</td>
<td>External fixator alone</td>
<td>Extra- and intra-articular malunion</td>
<td>Pain</td>
<td>38°</td>
<td>16</td>
</tr>
<tr>
<td>53 years</td>
<td>Dominant wrist</td>
<td>Then external fixator + pins</td>
<td>Dorsal deformity</td>
<td>VAS: 4</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Extra- and intra-articular fracture</td>
<td>Pins</td>
<td>Intra-articular malunion</td>
<td>Stiffness</td>
<td>42°</td>
<td>24</td>
</tr>
<tr>
<td>48 years</td>
<td>Dominant wrist</td>
<td>Neglected joint lesion</td>
<td>Dorsal and central deformity</td>
<td>Pain</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Neglected old injury</td>
<td>Cast immobilization</td>
<td>Post-traumatic radio-ulnar and radio-ulnar osteoarthritis</td>
<td>Stiffness</td>
<td>38°</td>
<td>10</td>
</tr>
<tr>
<td>74 years</td>
<td></td>
<td></td>
<td></td>
<td>VAS: 8</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>Joint fracture</td>
<td>Extrafocal pins</td>
<td>Intra-articular malunion</td>
<td>Stiffness</td>
<td>40°</td>
<td>14</td>
</tr>
<tr>
<td>18 years</td>
<td>Non dominant wrist</td>
<td></td>
<td>Dorsal joint deformity</td>
<td>Pain</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>Joint fracture</td>
<td>Intra- and extrafocal pins</td>
<td>Abrasion of palmar part of cartilage</td>
<td>Stiffness</td>
<td>70°</td>
<td>16</td>
</tr>
<tr>
<td>31 years</td>
<td>Non dominant wrist</td>
<td></td>
<td>Palmar deformity</td>
<td>Pain</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>Scaphoid malunion</td>
<td>Osteosynthesis</td>
<td>Abrasion of palmar part of cartilage</td>
<td>VAS: 7</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>38 years</td>
<td>Non dominant wrist</td>
<td>Possible scaphoid sepsis</td>
<td>Palmar deformity</td>
<td>VAS: 6</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1  Top: clinical view in the dorsal decubitus position, the anterior edge of the ribs is drawn on the skin as is the anterior iliac crest (AIC). In general, the bone–cartilage junction of the rib is projected on the nipple/AIC line or slightly medial. Bottom: clinical view in the dorsal decubitus position, the anterior edge of the ribs is drawn on the skin as well as the AIS. The graft drawn is harvested on one of the last ribs.

MRI imaging were performed at 6 months so as to visualize the reconstructed joint surface. During material removal, a fine-needle biopsy of the cartilage graft was performed to evaluate its viability.

Surgical technique

First phase
None of the patients was treated in an ambulatory setting. Under locoregional and then general anesthesia when the graft was harvested, the radius was approached from the lesioned side with a dorsal approach in the third compartment or a Henry approach. The joint capsule was opened with a Z incision when the dorsal approach was used. The joint destruction zone of the radial epiphysis was resected through an epiphyseal-metaphyseal cut.

Figure 2  Sagittal and frontal CT slice 6 months after a high-energy fracture showing subluxation with fixation (patient 1, male, 22 years old).

Figure 3  Intraoperative aspect of a costal graft harvested at the bone–cartilage junction; left, the cartilage is lighter and can be identified because it is softer.
### Table 2  Postoperative results.

<table>
<thead>
<tr>
<th>Patients Preoperative delay</th>
<th>Surgical procedure</th>
<th>Follow-up (months)</th>
<th>Pain</th>
<th>Flexion/extension</th>
<th>Wrist strength</th>
<th>DASH</th>
<th>Return to work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 22 years 6 months</td>
<td>Costal graft + dorsal plate</td>
<td>42</td>
<td>Barometric pain VAS: 2</td>
<td>155° 97%</td>
<td>48 kgf 82%</td>
<td>8.3</td>
<td>Return to work at 6 months, no activity limitation Physical labor</td>
</tr>
<tr>
<td>Male 5 years 12 months</td>
<td>Extra-articular cure of malunion (osteotomy)</td>
<td>36</td>
<td>Barometric pain VAS: 4</td>
<td>96° 69%</td>
<td>36 kgf 73%</td>
<td>21.7</td>
<td>Then early retirement</td>
</tr>
<tr>
<td>Male 48 years 24 months</td>
<td>Extra-articular cure of malunion, costal graft + palmar plate</td>
<td>24</td>
<td>Barometric pain VAS: 4</td>
<td>96° 74%</td>
<td>40 kgf 62%</td>
<td>21.7</td>
<td>Work position adapted</td>
</tr>
<tr>
<td>Male 74 years 36 months</td>
<td>Ulnar head resection + costal with palmar plate</td>
<td>24</td>
<td>Barometric pain VAS: 2</td>
<td>68° 54%</td>
<td>22 kgf 68%</td>
<td>7.5</td>
<td>Retired</td>
</tr>
<tr>
<td>Female 18 years 6 months</td>
<td>Costal graft + palmar plate</td>
<td>6</td>
<td>Barometric pain VAS: 2</td>
<td>98° 67%</td>
<td>18 kgf 60%</td>
<td>8.3</td>
<td>Return to work 6 months</td>
</tr>
<tr>
<td>Female 31 years 13 months</td>
<td>Costal graft + palmar plate</td>
<td>36</td>
<td>VAS = 0</td>
<td>140° 87%</td>
<td>18 kgf 92%</td>
<td>8.3</td>
<td>Return to work 5 months</td>
</tr>
<tr>
<td>Female 38 years 6 months</td>
<td>Costal graft + dorsal screw + scaphoid resection</td>
<td>24</td>
<td>VAS = 4</td>
<td>64° 45%</td>
<td>12 kgf 40%</td>
<td>52.5</td>
<td>Did not return to work</td>
</tr>
</tbody>
</table>

**Second phase**

Costal graft harvest (Fig. 1). The harvest procedure was performed through a horizontal incision, with the anterior cartilaginous extremity of the 7th, 8th, or 9th rib exposed. The difference in color makes the osteochondral junction, which projects 1 cm medially from the line extending from the nipple to the anterior iliac crest, easy to identify [5]. The deep side of the rib chosen is dissected cautiously. The graft is harvested using a scalpel. The rib harvest is extraperichondrial. If the rib is sufficiently wide, the graft can be harvested without breaking costal continuity. At the end of the harvesting procedure and in collaboration with the anesthesiologists, positive pressure insufflation was used to verify pleural integrity. A subcuticular suture was used to close the wound, with a Redon drain, after closing the intercostal muscles and subcutaneous cell tissue.

**Third phase**

Interposition of the cartilaginous autograft (Figs. 2—4). The graft was easily remodeled with a scalpel to the size of the corresponding cavity in the radial epiphyseal zone to be reconstructed, with the reddest bony part proximal and the whitest cartilaginous part in contact with the lunatum. The graft was then fixed using K-wires, cannulated screws, or an osteosynthesis plate in thin malleable titanium alloy. The skin was sutured using a subcuticular suture. After 2 days with a compressive bandage, immobilization (plaster short-arm cast in the position of hand function, leaving the thumb column and the interphalangeal joint free) was imposed for 90 days for patient no. 1 and for 21 days for the other patients. During pin or plate removal, a fine-needle biopsy of the cartilage graft was performed to assess its viability.
Figure 4  Intraoperative aspect (patient 1, male, 22 years old). Left: the defect created by excision of the subluxated and destroyed zone of the distal radius; middle: the chondrocostal graft is in place after reduction of the subluxation (the proximal bony part is darker); right: plate fixation.

Results

All patients were followed up prospectively at 1, 1.5, 3, 6 months, and then every year and seen with a mean follow-up of 26 months (range, 6–40 months) (Table 2, Figs. 5–7). One case was considered a failure in view of the worsened results. This was a patient presenting a periscaphoid problem that was likely septic, in whom resection of the scaphoid that was associated with the reconstruction of the joint surface of the radius opposite the lunatum, where the bony defect was underestimated, was insufficient to provide pain relief. Pain reduction was constant with a mean VAS at 2.5 (range, 0–4) and was accompanied by functional improvement: flexion–extension at 102° (range, 64–155°) (69% improvement), with an increase in wrist strength to 70% of the contralateral side (27 kgf (range, 12–48 kgf). The DASH score reached 18.3 (range, 7.5–52.5). The results were better in patient no. 1, the youngest of the series, who presented constitutional laxity, explaining the results that nearly matched the contralateral side. In addition, patient no. 2 had an extra-articular component that required resolution at the same time. Biopsies taken in the bony and cartilaginous zones during pin or plate removal showed viable cartilage and bone in both cases. X-rays and MRI at the latest follow-up did not show bone necrosis on the bone side or metaplasia on the cartilaginous side. No pleuropulmonary complication was noted intraoperatively. No complication at the donor site was reported, even in the three women in whom the scar was under the breast.

Discussion

What treatments are possible in cases of joint malunion?

In cases of intra-articular malunion of the radius, radiolunate arthrodesis has been reported by Saffar [6] in 11 patients with pain reduction around the 4th month, mean flexion–extension 72°, and wrist strength equal to 57% of the contralateral side. One year earlier, Foucher had reported on a technique that prevented loss of mobility using the Die Punch technique [7]. Nagy and Buchler [8] reported the results of radioscapholunate arthrodesis in 17 patients, but they underscored the poorer results in patients who had undergone multiple operations before the arthrodesis procedure. They emphasized the good tolerance of mediocarpal osteoarthritis and the relation of poor results with technical errors or complications. To reduce the number of interventions before arthrodesis, synonymous with poor results, Freeland et al. [9] reported the results of emergency arthrodesis (radiocarpal arthrodesis associated with resection of the first row of carpal bones) in the context of a non-reconstructible fracture of the distal radius. Four years before, Terall and Freeland had reported emergency placement of a Swanson implant in the wrist in the same circumstances [10]. Radiocarpal arthrodesis remains a classical solution, in view of the literature, of joint malunion of the distal radius. Even if in several series of arthrodesis joint malunions are not the sole condition [11,12], the conclusions are unequivocal: even though patients report they would undergo the surgery again, 80% of them experience discomfort in their daily activities [12], and reclassification can be problematic for those engaged in physical labor [12]. More recently, in cases of minimal lesion of the joint surface, Hoel reported a technique in two cases of subchondral bone reduction with symptom improvement [13]. Gobel et al. reported their experience and the contribution of arthroscopy in the reconstruction of malunions that remained malleable [14]. Finally, total arthroplasty can also be discussed if the osteocartilaginous defect is substantial and osteoarthritic advanced in a patient not engaged in physical labor with a high demand for mobility. Denervation alone or associated with the above-mentioned procedures is always possible.
Cartilage graft

Costal cartilage is part of the classical therapeutic armamentarium in maxillofacial surgery used to reconstruct the concha [15] or the mandibular condyle in both adults and children [16,17], based on harvesting the osteocartilaginous junction of the fifth and sixth ribs. The free costal cartilage graft has never been reported as a potential solution in joint malunion of the distal radius.

In our experience, the chondrocostal graft is a classical therapeutic solution in rhizarthrosis [18]. Later, Trumble et al. [19] published a technique with results comparable to ours. We also used the cartilaginous graft in pseudarthroses of the scaphoid with osteoarthritis and necrosis of the proximal pole, with functional results preserving greater mobility, in our experience, than partial arthrodesis or resection of the first row of carpal bones [20]. In cases of necrosis of the proximal pole, Sandow reported the same results in terms of pain and function [21]. Svensson et al. [22] studied the source of vascularization to explain the survival of the graft and its constant integration. For the bony side, vascularization comes from the receiver bone, and for the cartilage, it came from the soft tissues and the joint environment through imbibition. The kinetics of the appearance of vascularization is faster on the cartilage side [22]. It is possible to observe bone metaplasia on the cartilage side of the graft, which is clearly visible on simple images. Costal cartilage containing hyalin cartilage has the characteristics of an epiphyseal plate [23,24]. This was never the case in this small group of patients. Sequelae at the donor site were rare.

Figure 5  Postoperative aspect before (lateral X-ray) and after (AP X-ray) ablation of the radiocarpal wire of the temporary radiocarpal arthrodesis.

Figure 6  Radiographic and MRI aspect at 2 years: the graft is viable with no metaplasia.
(three pleural breaches out of 186 samples harvested in the team), with only one requiring drainage. At the donor site, the patients considered that this involved discomfort more than pain. This discomfort was reported by one out of two patients for 2–3 months. This consequence can be improved by continuous harvesting without interrupting costal continuity. The length of the hospital stay was not affected by harvesting cartilage.

**Conclusion**

Chondrocostal graft reconstruction is simple (adaptation to the defect, fixation), transmissible, and reliable. It allows resurfacing in cases of joint malunion with cartilage destruction or when there is no possibility of reducing joint impaction. Partial or total arthrodeses are classical solutions but their functional results are difficult to predict in wrists that are painful or have undergone several surgeries. The absence of other conservative solutions to reconstruct a destroyed joint surface is the main argument justifying this operative technique that has not been reported until now. This technique can only be used with incomplete destruction of the joint surface, which is often the case. The best treatment remains rigorous management of joint fractures of the distal radius in the patient with high functional demands.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

**References**


