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Reconstruction of Distal Radius Osteochondral Defects Using Metatarsal Autografts: a Multi-case Series

Reconstrucción de defectos osteocondrales del radio distal usando autoinjertos del metatarsiano: una serie de múltiples casos

Patrick K.Y. Goon[1] Shirley D. Stougie[1] Kalpesh R. Vaghela[1] J. Henk Coert[1]

[1] Department of Plastic Surgery and Hand Surgery, University Medical Center Utrecht, The Netherlands

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Address for correspondence J. Henk Coert, MD. PhD, Department of Plastic Surgery and Hand Surgery, University Medical Center Utrecht, P.O. Box, 3508AB, Utrecht, 85060, The Netherlands (e-mail: j.h.coert@umcutrecht.nl).

Abstract

Objective Delayed reconstruction of the articular surface of the distal radius after trauma is a difficult problem for hand surgeons, and the common solution is usually partial or total wrist fusion, relieving pain but sacrificing motion. A relative novel reconstructive technique addresses the problem with a free microvascular osteochondral flap, using the 3rd metatarsal (3MT) bone. We investigate the possibility of using the same donor as a graft rather than a free flap.

Methods This was a prospective clinical study of patients with isolated lunate facet damage following trauma who underwent surgery to remove the damaged articular surface and in whom the defect was reconstructed with an osteochondral graft from the base of the 3MT. All of the patients were followed-up at specific time intervals, with pre- and postoutcome measures taken, including pain, grip strength, range of motion (ROM), and postoperative radiographs and computed tomography (CT) scans to evaluate graft resorption and union. Only patients with isolated distal radius defects were included.

Results The average follow-up period was of 51 months (range: 14–73 months). The results of 7 patients included an average improvement of the pain score in the visual analogue scale (VAS) by 3 points, with an average arc of motion of 135°. In all, there was radiographic evidence of full incorporation of the graft, with no resorption. Donor site morbidity was minimal.

Conclusions The current gold standard for distal radius articular surface reconstruction remains a free 3MT osteochondral flap. However, our results using the base of the 3MT as a graft shows promise, and if further follow-up confirms comparable results to the free flap technique, this would mean an easier and equally robust reconstruction without complicated microsurgery.

Level of Evidence Therapeutic, Level V case series.

Keywords
- metatarsal
- reconstruction
- distal radius

Resumen

Objetivo La reconstrucción tardía de la superficie articular del radio distal después un traumatismo es un problema difícil para los cirujanos de la mano y por lo general, la solución mas común es la artrodesis parcial o total de muñeca, lo que disminuye el dolor, pero sacrifica la movilidad. Una técnica reconstructiva relativamente nueva, trata

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el problema mediante un injerto libre osteocondral, usando el hueso del tercer metatarsiano (3MT). Se presenta la posibilidad de utilizar el mismo hueso donante como injerto sin ser un colgajo libre.

Métodos Se realizó un estudio clínico prospectivo en pacientes con una lesión postraumática aislada de la fosa del semilunar en los que se realizó la cirugía para resecar la superficie articular dañada y en los que el defecto fue reconstruido mediante un injerto osteocondral de la base del 3MT. En todos los pacientes se realizó un seguimiento a intervalos de tiempo específicos y se recogieron las medidas pre y postoperatorias de dolor, fuerza de puño, rango de movimiento (ROM), y se realizaron radiografías y TAC postoperatorios para la evaluación de la reabsorción o consolidación del injerto. Solo se incluyeron pacientes con defectos aislados del radio distal.

Resultados El tiempo medio de seguimiento fue de 51 meses (intervalo: 14-73 meses). Los resultados de 7 pacientes incluyeron una mejora media de la puntuación del dolor en la escala analógica visual (VAS) de 3 puntos, con un arco de movimiento promedio de 135°. En todos, los casos, hubo evidencia radiográfica de plena consolidación del injerto, sin reabsorción. La morbilidad de la zona donante fue mínima.

Conclusiones Tratamiento "oro" en la actualidad para la reconstrucción de la superficie articular del radio distal continúa siendo un colgajo osteocondral libre del 3MT. Sin embargo, nuestros resultados utilizando la base del 3MT como injerto no vascularizado, son esperanzadores, y si el mayor seguimiento confirma que los resultados son comparables a la técnica usando un colgajo libre, significaría una reconstrucción más fácil y igualmente segura sin el uso de una técnica microquirúrgica complicada.

Nivel de evidencia Terapéutica, serie de casos de nivel V.

Palabras clave
- metatarsiano
- reconstrucción
- radio distal

Introduction

The common but difficult scenario of a distal radius intra-articular malunion after a fracture continues to pose a problem for upper limb surgeons. When consisting of an uncomplicated step deformity, this would be amenable to corrective osteotomy, but when there is substantial loss of articular cartilage with or without severe irregularity of the distal radius joint surface, salvage partial arthrodesis or arthroplasty may be the only options left.[1–3] These procedures provide good pain relief but result in a stiffer wrist. Frequently, these procedures change the kinematics of the wrist, resulting in further arthrosis and in the need for further salvage surgery.[2,4] Recently, del Piñal et al reported on their results using a vascularized 3rd metatarsal (3MT) osteochondral flap to resurface the distal radius in the presence of intact cartilage of the proximal scaphoid and lunate, with encouraging mid-term results.[5,6] Using the same donor site, we present our experience using the base of the 3MT as an autograft for similar resurfacing.

Materials and Methods

Between 2011 and 2014, 7 patients underwent reconstruction of the distal radius with a 3MT autograft. All of the patients had sustained closed fractures of the distal radius, with 4 treated with open reduction and fixation initially, and the remaining 3 patients treated nonoperatively, in different institutions, before referral. The mean time interval from their original injury until their reconstruction was of 30 months (range: 6–132 months). The primary patient symptom triggering referral for reconstructive surgery was pain in most patients, followed by limitation in the active range of motion (AROM) in the wrist. In all of the patients, the lunate facet of the radius was the primary defect, with evidence of articular cartilage loss (►**Fig. 1**). All of the patients were fully aware of the treatment aims and understood the risks and possible benefits, and gave informed consent for the procedure. The procedure is not a new one,[2] but a simplification of a published and reported technique, and therefore required no ethics approval.

Preoperative Assessment

Preoperative plain X-rays and computed tomography (CT) scans were used to confirm the articular damage and loss of congruity of the radiocarpal joint, and also to assess its extent. Only patients with isolated facet damage nonremediable by simple osteotomy or arthroscopic debridement were selected for the procedure. Contraindications to the procedure included widespread damage to both radius facets, lunate and/or scaphoid articular damage, carpal malalignment, and near or complete loss of range of motion (ROM). These criteria are similar to those proposed by del Piñal et al.[6]

Surgical Technique

Donor Site

The harvest of the autograft is similar to that described by del Pinal et al,[5] except by the fact that the graft is harvested without any feeding vessels. Briefly, the position of the 3rd

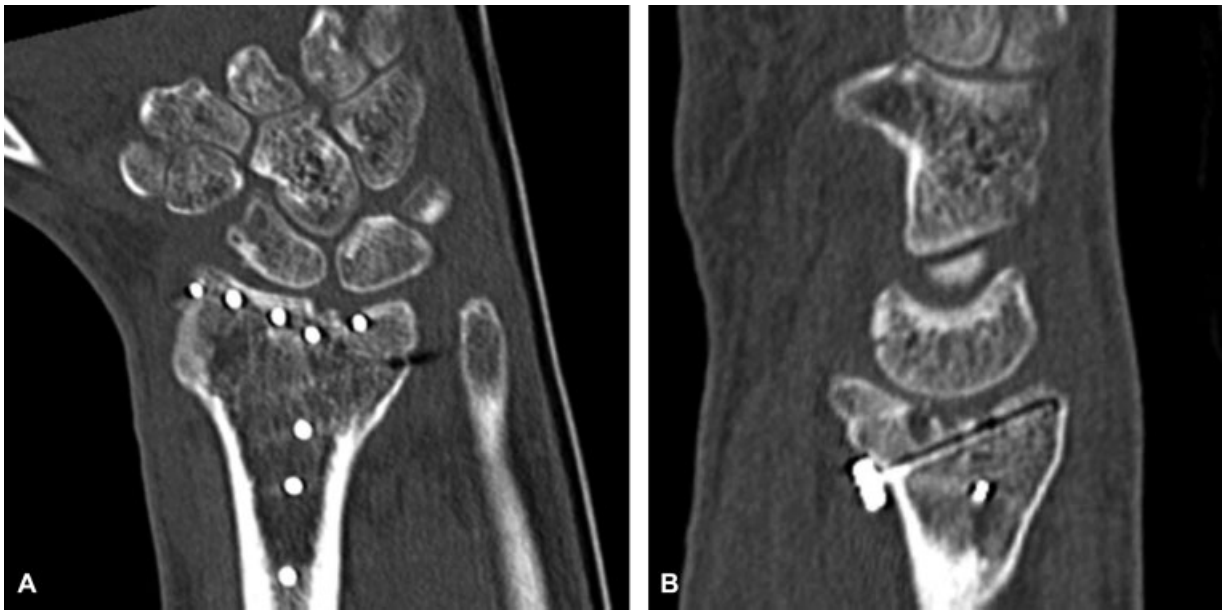

Fig. 1 Computed tomography scan of lunate facet irregularity and in-situ volar plate. Note the appearance of the distal screw in the articular defect in the lunate facet.

tarsal-metatarsal joint is identified with the help of a fluoroscopy scan and its surface markings are noted prior to the incision on the skin. Under tourniquet control, a lazy s incision over the joint is made, and the extensor digitorum and extensor hallucis brevis tendons are retracted laterally to expose the joint. The joint capsule is reflected via an I-shaped incision, exposing the base and the joint of the 3MT. The base of the 3MT is cut transversely with an oscillating saw, $\sim$ 1.5 cm distal to the joint, and taking care to avoid any damage to the articular cartilage, the graft is levered free of its soft tissue attachments. We leave the volar rim intact to preserve the insertion of the plantar ligaments. The resultant defect is not filled, but the dead space is left to fill with hematoma, thus encouraging soft tissue scarring comparable to resection arthroplasty of the base of the thumb. Closure is in layers after careful hemostasis. A foot splint is applied in a neutral position, and worn for 2 weeks. Supportive shoes with laces are worn for up to 6 weeks.

Recipient Site

With the arm exsanguinated, the wrist is approached dorsally via a longitudinal midline incision, and the extensor retinaculum is incised using a Z-shaped incision, opening up only the 3rd and 4th compartments. The terminal end of the posterior interosseous nerve is excised and the extensor tendons are retracted. Next, a rectangular, distally based, capsular flap incorporating the radiotriquetral ligament is raised, exposing the distal end of the radius with its dorsal lip. After flexing the wrist, the lunate is inspected to assess its articular surface and the quality of the cartilage, before addressing the radius proper. In some cases in which the proximal carpus (lunate or scaphoid) has migrated proximally due to the bone/cartilage defect in the radius, the adjunctive use of intraoperative traction (either via a generic finger trap and tower system; or a temporizing spanning external fixator) may be indicated, to allow easier resection of the damaged facet, as well as accurate sizing of the graft needed. This is important for accurate reconstruction of the facets; failure to do this may result in noncorrection of the proximal displacement of the lunate or of the scaphoid.

The affected area of the distal radius (in this series, all of the patients underwent excision of the damaged dorsal aspect of the lunate facet; ►**Fig. 2** Type A) is carefully removed as a rectangle, with the aid of an oscillating saw, at the same time leaving intact a medial pillar of bone. If the reconstruction includes sigmoid notch resurfacing, then the medial pillar is sacrificed as well (►**Fig. 2** Type D). The resultant three-dimensional defect should include some metaphyseal bone, to better accommodate the graft. In cases in which the medial cortical pillar is preserved (usually with a width of at least 5mm), the graft is tailored to fit the defect by removing the medial, lateral and volar cortices, to allow cancellous to cancellous bone apposition (►**Fig. 2** Type A and B). If the sigmoid notch is being reconstructed, then the accessory facet is preserved (a further point being that the contralateral 3MT must be harvested, to allow for correct orientation of the accessory facet). The graft is wedged or 'press fit' into place, its original 'plantar-dorsal' orientation now described as 'volar-dorsal', except case the sigmoid notch is reconstructed (in this case, the contralateral graft is orientated into a dorsal-volar position, to ensure the accessory facet faces ulnarly). The graft is held securely by the pillars of bone on both sides, and the articular surface is checked to ensure no step-off is evident. Fixation is via two or three corticocancellous screws or via buried Kirschner wires (►**Fig. 3**). The wrist is closed in a layered manner, with meticulous repair of the dorsal capsular flap (if needed, with a drill hole through the radius for fixation), with the wrist in neutral position for flexion and extension, and pronation and supination. Passive exercises commence at week 2, with

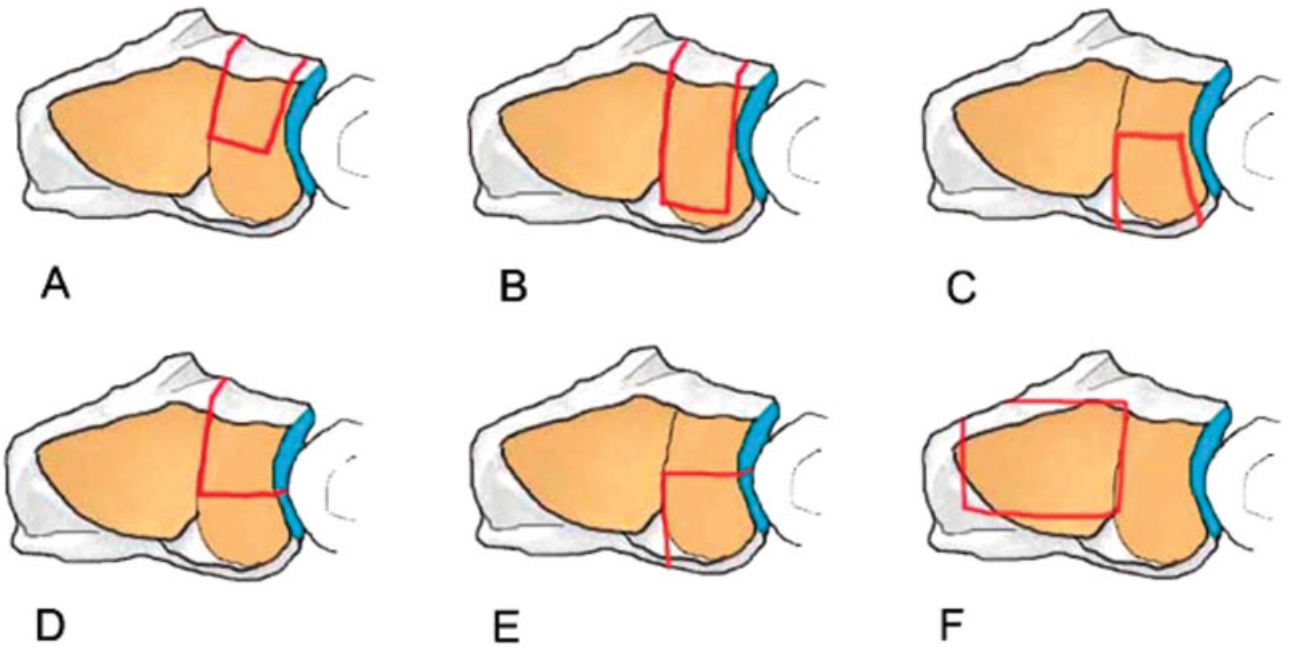

Fig. 2 Diagrammatic representation of the various distal radius reconstructions possible with the 3rd metatarsal autograft. The lunate and scaphoid facets are highlighted (brown), as well as the sigmoid notch (blue). Please note that this is only a diagrammatic rendition of the distal radius and, therefore, it, as well as the reconstructions (red), are not strictly to scale. The possible permutations for facet resurfacing are extrapolated from the anatomical work of del Piñal.[5]

active assisted exercises beginning at week 4. The total time requiring splinting was 6 weeks in most cases.

Results

Seven patients underwent lunate fossa reconstruction and 1 underwent concurrent sigmoid notch resurfacing. An average of 51 months follow-up was attained (range: 14–73 months). The preoperative visual analogue scale (VAS) for pain was 4 (range: 0–7), compared with a postoperative score of 1 (range: 0–3). Postoperative CT scans and X-rays (►**Fig. 4**) at 6 months postoperatively were independently reported by musculoskeletal radiologists, confirming bridging trabeculae and, therefore, union of all grafts, with no evidence of avascular necrosis or resorption at that stage. No hardware loosening or overt signs of arthroses (subchondral cysts, or sclerosis) were seen. On average, extension increased by 21°, and flexion increased by 5°. The average total active flexion-extension arc was 119°, with an improvement of 28°. The average grip strength improved by 8.5 kg. Donor site morbidity was minimal, with pain being the primary complaint. This resolved after 3 months in most circumstances. No infective or hardware complications were noted in the latest follow-up. One patient (case 3) required tenolysis of his extensor tendons to the index finger to treat an extension contracture. Full details of patient demographics and surgical details are recorded (►**Tables 1** and **2**).

Discussion

Although it is well known that many patients with radiographic arthrosis after distal radius fractures do not have significant pain, there is a subset of patients who are

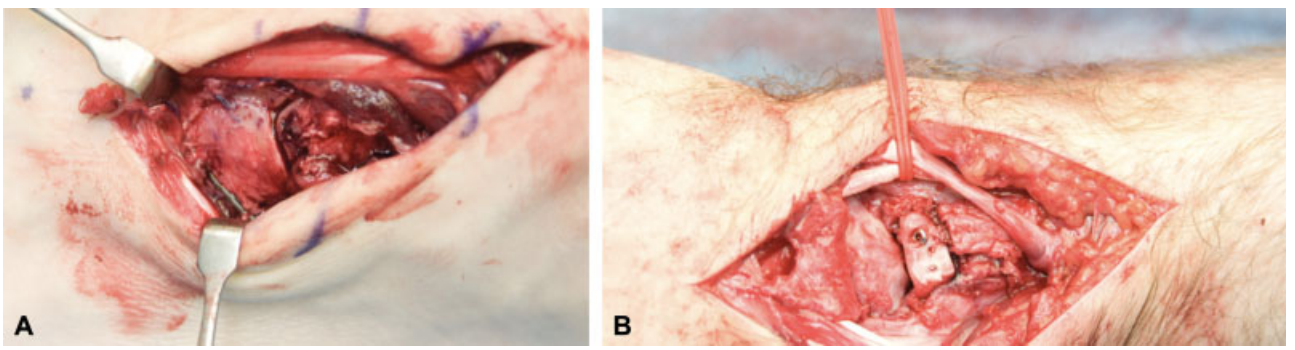

Fig. 3 (A) The dorsal lunate facet excised, showing the resultant defect. Medial and radial pillars of radius shown. Note the appearance of the lunate, being abnormally scarred rather than having the usual 'shiny' white appearance. This was a similar case to that demonstrated by del Piñal et al.[5] (B) The 3rd metatarsal autograft is inset by press fitting, and secured with screws and Kirschner wires.

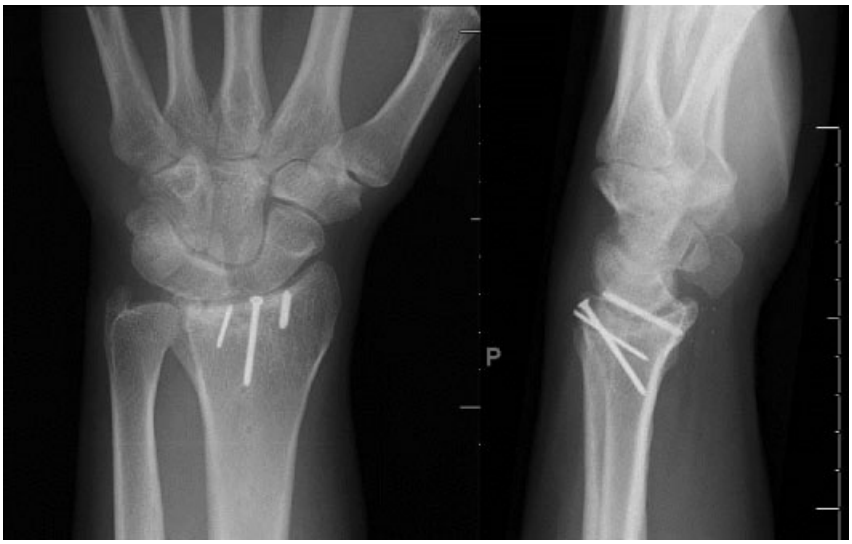

Fig. 4 An example of a 6-month follow-up X-ray demonstrating union of the autograft and good restoration of the radiocarpal articulation. A broken screw of the volar plate remains in the radius, but has no interference with the autograft.

troubled by pain, and require intervention. The treatment of distal radius defects with loss of articular cartilage is difficult and often limited to pain relieving procedures, such as denervation or (partial) arthrodesis. However, when the damage is focal rather than widespread, with no carpal instability or carpal articular cartilage loss, reconstruction becomes a viable option. Before the use of 3MT for reconstruction, sources of autografting, such as the costochondral rib,[7] the tibiofibular joint,[8] and most recently, the patellofemoral joint,[9] and the pisiform bone,[10] have been described, with encouraging results. With costochondral grafts, the group reported 7 patients who underwent reconstruction of the distal radius for malunion, with harvest of the graft from the 8th rib. Both ROM and pain scores improved

Table 1 Patient demographics

Age (years old)	Gender	Dominance	Follow-up (months)	Occupation	Delay (months)	Initial Rx	Addt Rx
26	M	D	18	Student	19	Volar plate	Arthroscopic shaving osteophyte
43	M	ND	69	Farmer	132	?	Bone graft from pelvis
27	M	ND	67	Physiotherapist	9	?	?
46	M	ND	73	Carpenter	13	?	?
28	M	D	61	Roofer	24	?	Plate removal
21	M	ND	14	Nursing student	6	?	?
51	F	ND	57	Manager H&R	7	?	?

Abbreviations: Addt, additional; D, dominant; F, female, H&R, human resources, M, Male, ND, non dominant; Rx, X ray.

Table 2 Intraoperative findings and management

Patient	Reconstructed area	Carpal cartilage status	Graft fixation	Additional procedures
1	Lunate fossa	Normal	Screw	Plate removal
2	Lunate fossa	Normal	2 x Kirschner wire	–
3	Lunate fossa	Normal	1 x Kirschner wire	–
4	Lunate fossa	Normal	Screw + Kirschner wire	–
5	Lunate fossa	Normal	Kirschner wire	Repositioning of the lunate
6	Lunate fossa and sigmoid notch	Normal	Screw + 2 x Kirschner wire	–
7	Lunate fossa	Normal	Kirschner wire	–

significantly. On early follow-up CT scans (6 months), no evidence of graft resorption was seen.[7] However, with long-term follow-up (6 patients), there was lysis/resorption of 1 graft.[11] Reported complications include donor site morbidity, including potential life-threatening thoracic complications. There is now more evidence suggesting frequent cartilage and bone resorption with autografting in the wrist and in the hand.[6]

Others have successfully used free vascularized fibular flaps,[12,13] in an attempt to obviate the problem of resorption. The disadvantage of this technique is the obvious incongruity of the reconstructed joint with that of the proximal carpus, leading to frequent degenerative arthrosis in the long-term. In 2005, del Piñal et al[5] published preliminary results of cadaveric studies, and 1 patient for whom a novel osteochondral free flap from the 3MT was chosen. The decision to use this donor included its size and shape, the presence of a consistent accessory facet, the low donor site morbidity, and the ability to raise the bone cartilage unit as a free flap, complete with a robust vascular pedicle and even a monitoring skin flap.

The 3MT is a good choice of donor (►**Fig. 5**) bone and cartilage for resurfacing substantial areas of distal radius articular surface due its qualities and size (19 mm dorsoplantar length, 12mm dorsal width, and 8 mm plantar width), and allows for partial or near total resurfacing of either the lunate or of the scaphoid facet. In a study by del Piñal et al,[5] it was noted that the principal facet is usually flat or slightly concave, and slanted distally from dorsal to plantar and from fibular to tibial, making it suitable for the reconstruction. Notably, the 3MT is unique in that it has a fairly constant accessory facet on its fibular side, articulating with the base of the 4th metatarsal, and is suitable for concurrent reconstruction of the sigmoid notch of the radius, bearing in mind that resurfacing of the sigmoid notch is partial at best, due to the maximum size constraints of the donor.

The advantages include a reliable blood supply to the 3MT graft, thus both the subchondral bone and the articular cartilage are vascularized immediately, without the need for survival and nutrition from synovial fluid or the necessary survival and incorporation of the graft bone via osteoconduction.[5] As demonstrated previously, the articular cartilage is inherently dependent on subchondral bone vascularity for its survival, otherwise chondrolysis is likely.[14] Therefore, the problems of bone and chondral resorption are reduced with immediate vascularization, compared with autografting.[6] The other advantages would be the concave shape of the proximal base of the 3MT, which is a good anatomical match for the lunate and scaphoid facets, as well as for the accessory facet, making possible the reconstruction of the sigmoid notch. Our own results support this view, with a mean arc of 119° at the wrist, and a significant reduction in pain. Important reasons for reduction in pain would most likely include the "denervation" effect of reconstruction surgery, the deliberate division of the posterior interosseous nerve terminal branch, as well as the restoration of joint anatomy and of the carpal height. It is important to add that the relief of pain due only to osteochondral resurfacing is impossible to quantify in the present study, due to the variables described above.

The advantages of using a nonvascularized graft as opposed to a vascularized graft are in the relative ease of harvest. There is no difficult dissection of arterial anatomy, a fact noted as well by del Piñal et al.[5,6] Hence, microsurgical skills are not needed, and the operative time is significantly reduced. Furthermore, the inherent risks of microvascular occlusion and prolonged stay in hospital are avoided. Donor site morbidity is also very acceptable to the patients,[6] and the risk of neuroma is lower, as there is minimal soft tissue dissection as opposed to raising a vascular pedicle. Also, the vascularized graft is more bulky when usually taken with a skin paddle, causing a more tedious insert and fixation of the osteochondral graft.

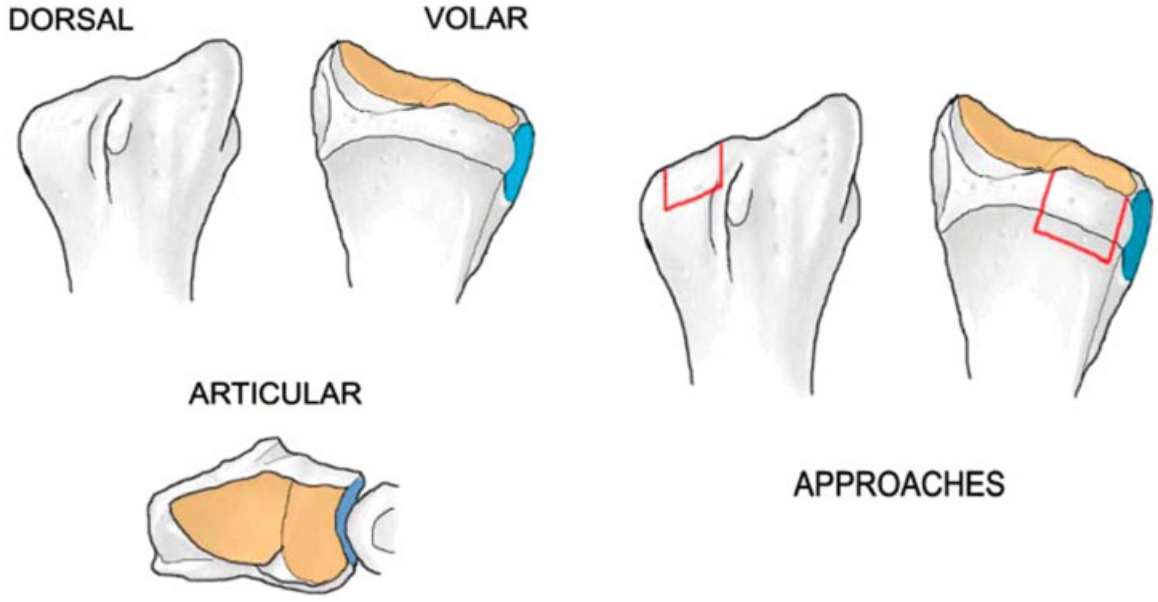

Fig. 5 Diagrammatic representation of the 3rd metatarsal, with the proximal facet (brown) and accessory facet (blue) shown. The point of resection is demonstrated by the red line.

The reconstruction presented here has demonstrated a quite acceptable mid-term pain reduction with 4 out of 7 patients without pain and an average VAS of 1.

As there is more metaphyseal than diaphyseal bone at the site of reconstruction, the very reliable and rapid graft harvesting in all of our cases may be explained by this. Furthermore, the preservation of the medial cortical pillar of the radius is important, since it increases significantly the surface area of cancellous bone to bone contact, and the method of 'press fitting' the graft further optimizes the graft harvesting conditions, as well as providing stability to the reconstruction. An added advantage is that the dorsal radial radioulnar ligament attachments, important for stabilizing the distal radioulnar joint (DRUJ), are preserved. Further scans (at 10 and 15 years of follow-up) will easily answer the potential issue of resorption in the mid- and long-term.

As stated, the proximal facet of the 3MT is usually mildly concave, making it suitable for distal radius reconstruction. However, on the rare occasion, it appears convex. In patient 6 of our series, this was noted. In such an uncommon scenario, it may be feasible to consider harvesting partially the distal 3rd cuneiform, rather than the 3MT, as the cuneiform distal facet will be concave. Such an assessment can be easily made intraoperatively or via preoperative CT scanning. We have not yet performed this autograft, but anticipate that donor site morbidity is no different from normal 3MT patients.

There are several obvious limitations in the present study, including the lack of long-term results. Furthermore, owing to poor patient compliance with pre- and postoperative follow-up sessions, the data are necessarily incomplete, and this precluded a robust statistical analysis. The 3MT vascularized graft procedure developed by del Piñal et al[5] remains currently the most viable method of anatomically resurfacing large areas of damaged distal radius articulation, and also concurrent sigmoid notch defects; our mid-term results would suggest that 3MT autografting achieves the same functional and radiological outcomes in the short-term, with the added advantage that no microsurgical techniques are necessary.

Conflicts of Interests

The authors have no conflicts of interests to declare.

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