

Radiocarpal Joint Reconstruction with a Double Free Metatarsophalangeal Joint Transfer

Pedro C. Cavadas, MD, PhD*†
Beatriz Padial, MD*

Background: Destruction of the radiocarpal and midcarpal joints causes loss of wrist motion, pain, and reduced grip strength. A novel technique for radiocarpal reconstruction is presented.

Methods: Two patients who had radiocarpal and midcarpal destruction and osteoarthritis underwent reconstruction using simultaneous bilateral microvascular second metatarsophalangeal joint transfer. The inseting was performed, inverting the distal-proximal orientation of both metatarsophalangeal joints and fixing them with two 2.0 screws in proximal and Kirschner wires in distal.

Results: Radiocarpal extension and flexion without pain were preserved after a minimum of 4 years follow-up. Both patients could return to recreational activities. No secondary procedures were needed.

Conclusions: This technique could be an alternative for radiocarpal reconstruction, although longer follow-up and more cases are needed. (*Plast Reconstr Surg Glob Open* 2023; 11:e5284; doi: [10.1097/GOX.0000000000005284](https://doi.org/10.1097/GOX.0000000000005284); Published online 28 September 2023.)

INTRODUCTION

Destruction of the radiocarpal and midcarpal joints causes severe disability because of loss of wrist motion, pain, and reduced grip strength. A painful wrist severely limits the use of the hand and the arm, decreases grip strength, and impairs quality of life.¹ Depending on the patient's characteristics, the available treatment is either wrist fusion or prosthetic joint replacement. The advantages and disadvantages of both modalities of treatment are well discussed in the literature.¹

From a biological standpoint, autologous reconstruction would be desirable in young, active individuals. Prosthetic joint replacements have unpredictable durability in this subset of patients, and arthrodesis results in obvious loss of motion. A novel technique of wrist reconstruction with simultaneous bilateral microvascular second metatarsophalangeal joint (MTPj) transfer is described. A cadaver feasibility study and two clinical cases with extensive radiocarpal and midcarpal osteoarthritis are reported. To the best of the authors' knowledge,

no similar technique has been reported before in the literature.

MATERIALS AND METHODS

Cadaver Feasibility Study

A feasibility trial was performed in a fresh-frozen anatomical specimen consisting of two feet and one forearm from the same individual without osteoarticular abnormalities on the X-ray. The surgical technique described below was performed in a simplified version, focusing on the bone inseting of the two MTPjs, obviating the vascular issues. The passive range of flexion-extension of the wrist approached 75% of that of the intact specimen, with extension more limited than flexion. (See Video [online], which displays the range of motion of the anatomic specimen with the wrist joint replaced with two MTPjs of the second toe. The cadaver feasibility study showed good lateral stability and excellent flexion-extension range of motion.) Lateral motion was minimal, as expected by the nature of the construction.

Surgical Technique

Under general anesthesia, the involved upper limb and the two legs are prepared with three independent tourniquet cuffs. The wrist is accessed through a standard

From *Reconstructive Surgery, Clinica Cavadas, Valencia, Spain; and †Departamento de Cirugía, Facultad de Ciencias de la Salud, Universidad Cardenal Herrera-CEU, CEU Universities, Valencia, Spain.

Received for publication May 16, 2023; accepted July 25, 2023.

Copyright © 2023 The Authors. Published by Wolters Kluwer Health, Inc. on behalf of The American Society of Plastic Surgeons. This is an open-access article distributed under the terms of the [Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 \(CCBY-NC-ND\)](https://creativecommons.org/licenses/by-nc-nd/4.0/), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

DOI: [10.1097/GOX.0000000000005284](https://doi.org/10.1097/GOX.0000000000005284)

Disclosure statements are at the end of this article, following the correspondence information.

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

dorsal approach with resection of the distal posterior interosseous nerve (PIN). A proximal row carpectomy is performed, including the proximal pole of the capitate. The distal radius epiphysis is resected, except for the volar cortex and the radial insertion of the triangular fibrocartilage complex (Fig. 1). The radial (or ulnar) artery, along with its venae comitantes (VC), and appropriate subcutaneous veins are dissected and prepared as recipients.

Simultaneous dissection of the bilateral MTPj is desirable but impractical in the authors' small team. Sequential elevation of the bilateral second MTPj free flaps is performed in the standard way, using a dorsal skin island as a monitor, and preserving the VC as an additional venous drainage. The first MTPj is left in place, perfused on its pedicle, until the second MTPj is fully dissected. Then both joints are transferred to the wrist (Fig. 2). Removing the second toes is optional, although it is recommended to the patients. The inseting is performed, inverting the distal-proximal orientation of both MTPjs (Fig. 1). Bone resection of the distal radius and the proximal capitate-trapezoid is completed to allow inseting of both MTPjs parallel to each other, without vascular compression or kinking. This is the most critical and difficult part of the surgery. The MTPjs are inset with the P1 proximal and the M2 distal, maintaining the dorsal-volar orientation (Fig. 1). The bases of the P1 are fixed to the distal radius with 2-mm screws, and the heads of the metatarsals, to the remnants of the capitate and trapezoid with 1.0-mm K-wires. The joints are fixed in mild extension with the wrist in neutral position to allow for wrist flexion. C-arm is used throughout to check correct alignment.

Takeaways

Question: Radiocarpal joint reconstruction in young patients.

Findings: A new technique of radiocarpal reconstruction using simultaneous bilateral microvascular second metatarsophalangeal joint transfer is presented. A cadaver feasibility study and two clinical cases with extensive radiocarpal and midcarpal osteoarthritis are reported. Radiocarpal extension and flexion without pain were preserved after a minimum of 4 years follow-up.

Meaning: This new technique allows an autologous reconstruction, desirable in young, active individuals.

Vascular anastomoses are performed depending on the dorsal or plantar arterial dominance of the toes, available recipients, and the geometry of the vessels after inseting. All vascular anastomoses are performed under tourniquet control for speed and accuracy. Both skin monitoring islands are sutured together on the dorsum of the wrist upon wound closure (Fig. 3).

The wrist is immobilized in a short arm plaster splint for 5 weeks, allowing active finger movement. The K-wires are removed on week 6, and passive and active movement of the wrist is then started.

The donor feet were elevated for 5 days. Progressive ambulation was allowed afterward with weight-bearing on the posterior sole. Normal ambulation was allowed after 4 weeks.

Informed consent was obtained from each patient. The study was approved by the local ethics committee and

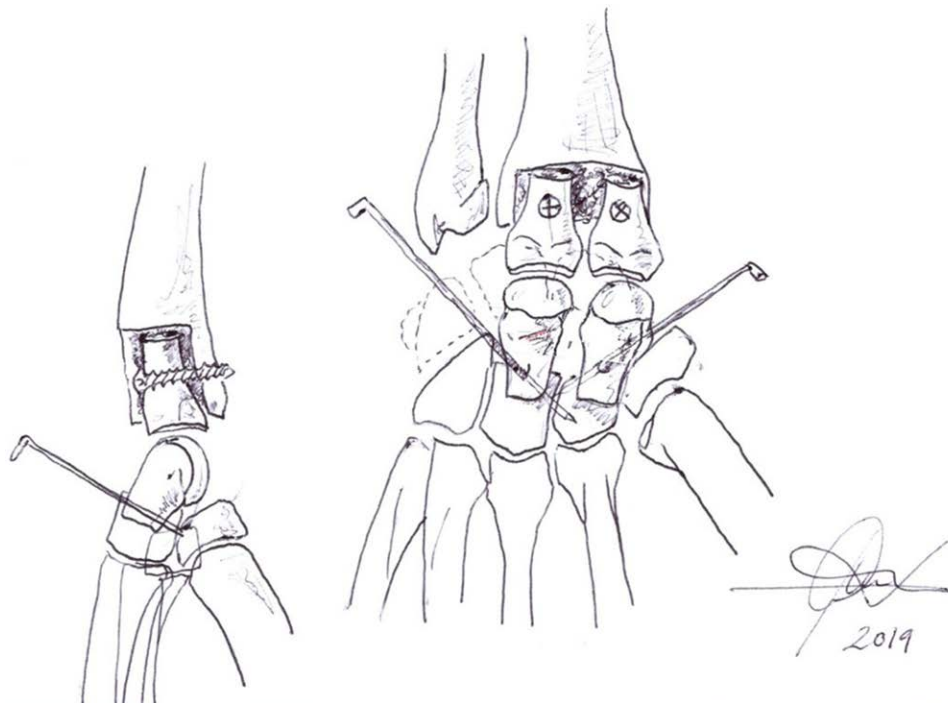


Fig. 1. Depiction of the general inseting of the double second-toe MTPj flaps. The volar-distal radius and the proximal carpus are resected and the MTPjs are inset inverted proximodistally in mild extension.



Fig. 2. The two second-toe MTPj free flaps before inseting.



Fig. 3. The two skin islands of the flaps sutured to each other. They can be excised later for improved cosmesis.

conformed to the Declaration of Helsinki. No quantitative grip strength or visual analog scale pain measurements were recorded pre- or postoperatively because of logistic limitations.

RESULTS

Case 1

A 34-year-old woman presented with left radiocarpal and midcarpal joint destruction, secondary to a dog bite 12 months before (Fig. 4). There were no clinical or laboratory signs of active infection. Wrist flexion-extension was minimal, with severe pain and limitation of activities of daily living. After full discussion with the patient about the treatment options and informed consent, an autologous vascularized reconstruction was decided upon.

The bilateral second-toe MTPj free flaps were inset as described above, and the vascular anastomoses were



Fig. 4. Extensive radiocarpal and midcarpal degeneration in case 1.

as follows: the plantar artery of the left MTPj end-to-side to the radial artery, two plantar VC to the radial VC, and the dorsal vein to the cephalic vein. The right MTPj plantar artery and one VC were anastomosed end-to-end to the plantar branch to the hallux of the left joint, and the dorsal vein was anastomosed to a side branch of the dorsal vein of the left MTPj (Fig. 5). Operating room time was 8 hours. The postoperative course was uneventful.

At 5 years postoperative, the active range of motion of the wrist was 30 degrees of extension and 40 degrees of flexion without pain (Fig. 6). Lateral motion was minimal. Mild X-ray changes occurred in the ulnar side of the MTPj located radially, consisting of a small osteophyte of the head of the metatarsal and geode in the base of the P1, with minimal narrowing of the joint line. There was no malalignment, and no functional impairment (Fig. 7). The patient resumed her normal life. No significant functional sequelae in the feet were reported by the patient (the second toes were removed).

Case 2

A 52-year-old, male, workers' compensation patient presented with radiocapitate osteoarthritis after proximal row carpectomy, complaining of pain and minimal wrist flexion-extension. The wrist was reconstructed with a simultaneous bilateral second-toe MTPj. Bone inset was as described in the surgical technique. Vascular repairs were as follows: a Y-shaped vein graft was used from the fourth common digital artery to both plantar arteries of the MTPjs, and the branches to the hallux were anastomosed to each other end-to-end as an internal shunt. The dorsal veins were anastomosed to separate branches of the cephalic vein (Fig. 8). No VC were repaired. Operating room time was 7 hours 40 minutes.

return to his previous employment but refers unrestricted recreational activity.

DISCUSSION

Painless wrist motion is paramount for activities of daily living. Although patients seem to adapt well to total wrist arthrodesis, motion-preserving surgery is usually preferred by the patients if given the choice.^{2,3} Although significant improvements in materials and design of newer implants have led to acceptable midterm results, the durability of these procedures, especially in young, active individuals, is still unpredictable.¹ Motion-preserving surgical techniques, such as proximal row carpectomy or scaphoidectomy plus four-corner (or capitolunate) arthrodesis, need anatomical integrity of some joints within the wrist and are thus not indicated in combined destruction of the radiocarpal and midcarpal joints. Autologous reconstruction of the wrist would be desirable in young, active patients with pan-carpal osteoarthritis. Although it is a well-established technique in elbow osteoarthritis, attempts at resection-interposition arthroplasty in the severely osteoarthritic wrist have yielded relatively poor results and are rarely performed.^{4,5}

Vascularized joint transfers are known to maintain anatomic integrity in the long term.⁶ Toe PIP or MTPj transfers have been used in finger reconstruction, especially in children^{6,7} and for thumb carpometacarpal joint reconstruction.⁸ The use of vascularized joint transfers for reconstructing medium-sized joints has been rarely reported,⁹⁻¹² and it is limited by the small size of available expendable donor joints (basically toe MTPjs). The use of a less expendable donor joint, the distal radioulnar joint, has been described as a pedicled vascularized transfer for radiocarpal reconstruction, with questionable risk-benefit ratio.¹³ The second-toe MTPj has been used for radiocarpal stability in radial hypoplasia by Vilkki and Paavilainen,¹⁴ with excellent results. The joint provided growth potential and radial support to the wrist joint but was not intended to replace the whole wrist joint.

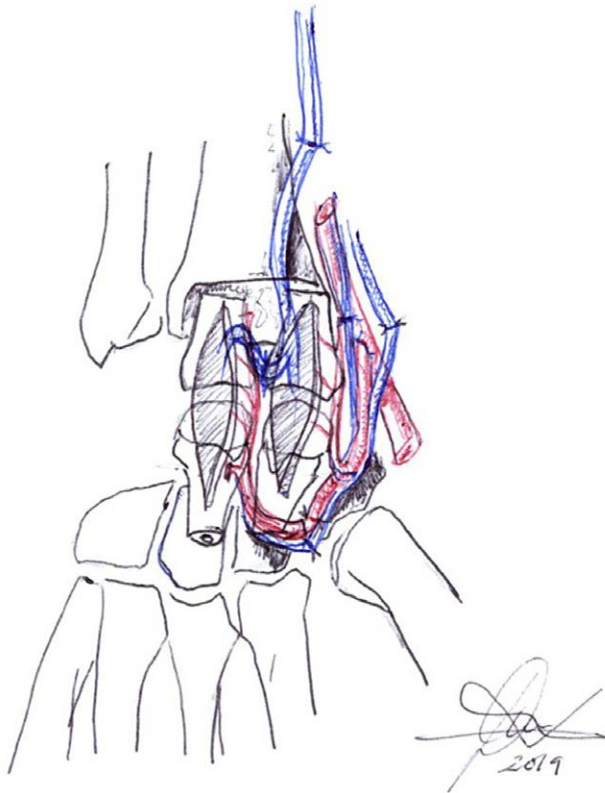


Fig. 5. Drawing of the vascular anastomoses in case 1: the plantar artery of the left MTPj end-to-side to the radial artery, two plantar VC to the radial VC, and the dorsal vein to the cephalic vein. The right MTPj plantar artery and one VC were anastomosed end-to-end to the plantar branch to the hallux of the left joint, and the dorsal vein was anastomosed to a side branch of the dorsal vein of the left MTPj.

At 4 years postoperative, the joints were well aligned and preserved in the X-ray (Fig. 9), and range of motion was 50 degrees of extension and 30 degrees of flexion, without significant pain (Fig. 10). The patient did not

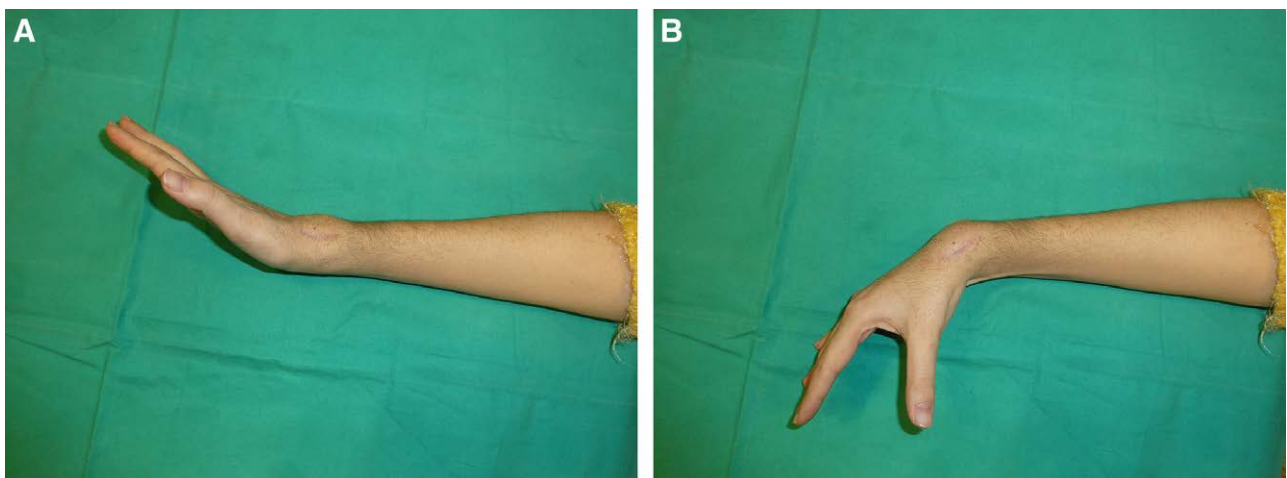


Fig. 6. Patient 1, a 34-year-old woman. A, Postoperative extension at 4 years follow-up. B, Postoperative flexion at 4 years follow-up.



Fig. 7. Patient 1 X-rays, at 4-year postoperative follow-up, showing well-maintained alignment and minimal changes. A, PA. B, Lateral.

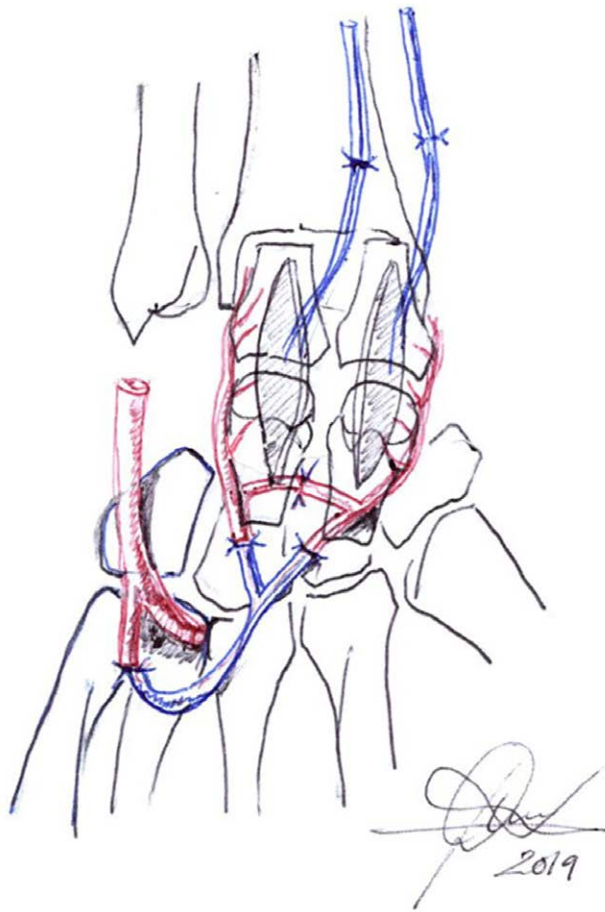


Fig. 8. Drawing of the vascular repairs in case 2: a Y-shaped vein graft was used from the fourth common digital artery to both plantar arteries of the MTPj and the branches to the hallux were anastomosed to each other end-to-end as an internal shunt. The dorsal veins were anastomosed to separate branches of the cephalic vein.

The biomechanics of the wrist is a combination of radiocarpal and midcarpal motion, and it is exceedingly complex to be duplicated by any currently available

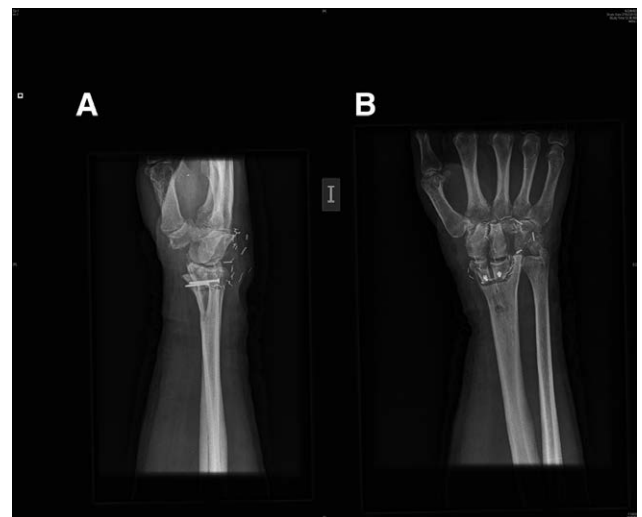


Fig. 9. Patient 2 X-rays at 3-year postoperative follow-up, showing well-preserved transferred joints. A, PA. B, Lateral.

technique. Simplistically, the midcarpal joint has been considered responsible for the dorsal-ulnar to volar-radial (dart-thrower's) movement, whereas the radiocarpal joint provides the reverse.¹⁴ Recent biomechanical studies suggest that both joints contribute equally to the dart-throwing motion.^{15,16} In the case presented here, the second-toe MTPj was used for reconstruction because of its familiarity of use to microsurgeons and its relative expendability. It is a glenoid joint with motion in the sagittal and coronal planes. One MTPj alone would probably lack lateral stability; so two joints, parallel to each other, with coaxial center of rotation offer the best combination of flexion-extension with lateral stability and low donor morbidity, at the expense of a complex inseting process and difficult microvascular connections. It did not duplicate the dart-thrower's motion, but allowed 70–80 degrees of combined, painless, flexion-extension range of motion.

The technique described allows for reconstruction of only one wrist. In bilateral cases, harvesting two MTPjs per

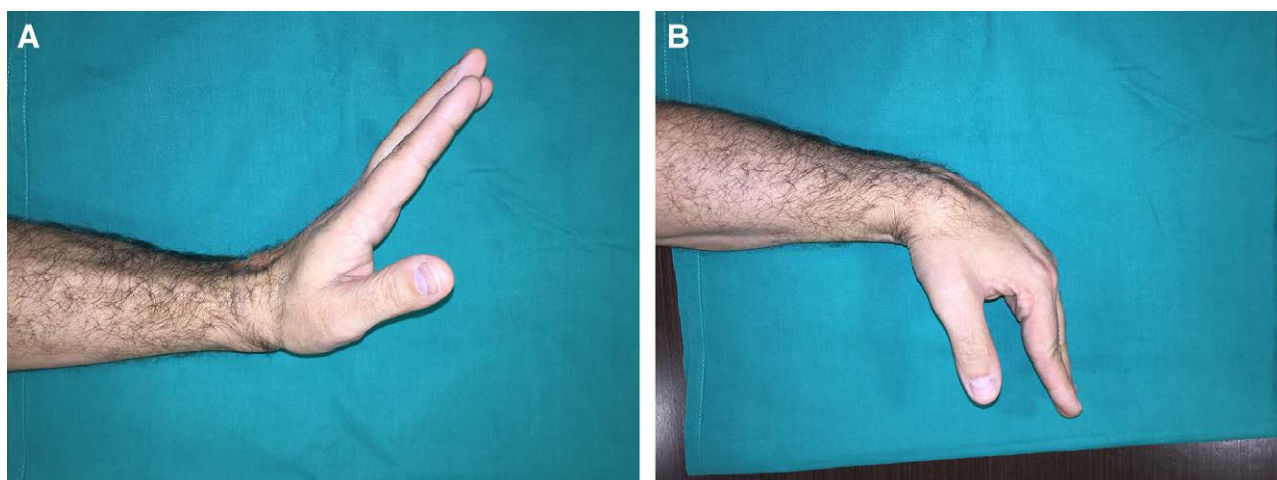


Fig. 10. Patient 2, a 52-year-old man. A, Postoperative extension at 3-year follow-up. B, Postoperative flexion at 3-year follow-up.

foot would be exceedingly morbid. The use of only one MTPj per side would be possible, with a mechanical construct resembling a proximal row carpectomy. The stability of this construct is yet to be demonstrated, although a recent, unpublished case by the author seems to preliminarily indicate enough stability of a single MTPj. More cases with adequate follow-up are needed before conclusions can be drawn in this regard.

Longevity is the key factor in joint reconstruction. Alloplastic joint replacement is the gold standard at present for most joints in the anatomy, although it has significant long-term complication rates, requiring revision surgery, proportional to the intensity of the functional demands. In small or medium-sized joint reconstruction, vascularized free joint transfers have demonstrated excellent durability.^{6–14}

The small size of available expendable joints is the limiting factor of its use in larger joint reconstruction. The use of the hallux MTPj has been reported for elbow reconstruction,⁹ with limited success and significant donor morbidity. The morbidity associated with hallux MTPj harvest is prohibitive to most patients. A single second-toe MPj may not be stable enough for wrist reconstruction, but two coaxial joints placed in the coronal plane have intrinsic lateral stability. The donor morbidity of bilateral second-toe MTPj is very limited.

Biomechanics of the double MTPj construct does not parallel the normal wrist and the transferred joints are subject to significant shearing forces. This may explain the mild degenerative changes seen in one of these patients at 4 years. In the two cases described, extension was better than flexion despite inseting in mild extension, probably due to the MTPj being an extension joint. Inverting the plantar-dorsal positioning would improve this problem, at the expense of complicating the skin island positioning.

Regarding pain relief, although no formal measurements were recorded, it was excellent in both cases. Because the division of the distal posterior interosseous nerve (PIN) was performed in the dorsal wrist approach,

it is impossible to estimate the impact of this maneuver in pain relief. Nonetheless, in the author's experience, isolated distal PIN division has no significant effect in relieving painful wrist conditions.

The study presented has clear limitations. It only includes two cases with midterm follow-up. No objective strength measurements or visual analog pain scales were recorded before or after the procedures, because of logistic limitations of the small team. The procedure is technically difficult and requires solid microvascular experience; its technical complexity, compared with existing alternatives, is a clear disadvantage. Longer follow-up and more cases are needed before this technique can be recommended, although the technique described herein could be an autologous alternative to wrist prosthetic replacement in young patients.

CONCLUSION

This technique could be an alternative for radiocarpal reconstruction in young patients, although longer follow-up and more cases are needed.

Pedro C. Cavadas, MD, PhD

Reconstructive Surgery, Clinica Cavadas

Paseo Facultades 1

Valencia 46021, Spain

E-mail: pcavadas@clinicacavadas.es

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Adams BD. Wrist arthroplasty partial and total. *Hand Clin.* 2013;29:79–89.
2. Vicar AJ, Burton RI. Surgical management of rheumatoid arthritis. Wrist fusion or arthroplasty. *J Hand Surg Am.* 1986;1:790–797.
3. Murphy DM, Khoury JG, Imbriglia JE, et al. Comparison of arthroplasty and arthrodesis in rheumatoid arthritis. *J Hand Surg Am.* 2003;28:570–576.

4. Carneiro S, Dias CE, Baptista CM. Proximal row carpectomy with allograft scaffold interposition arthroplasty. *Tech Hand Up Extrem Surg.* 2011;15:253–256.
5. Kwon BC, Choi SJ, Shin J, et al. Proximal row carpectomy with capsular interposition arthroplasty for advanced arthritis of the wrist. *J Bone Joint Surg Br.* 2009;91:1601–1606.
6. Hierner R, Berger AK. Long-term results after vascularized joint transfer for finger joint reconstruction. *J Plast Reconstr Aesthet Surg.* 2008;61:1338–1346.
7. Jones NF, Clune JE. Thumb amputations in children: classification and reconstruction by microsurgical toe transfers. *J Hand Surg Am.* 2019;44:519.e1–519.e10.
8. Roger de Oña I, García Villanueva A, Studer de Oya A. An alternative thumb reconstruction by double microsurgical transfer from the great and second toe for a carpometacarpal amputation. *J Hand Surg Am.* 2018;43:955.e1–955.e9.
9. Shibata M. Elbow joint reconstruction using metatarsophalangeal joint of the great toe. In: Tamai S, ed. *Experimental and Clinical Reconstructive Microsurgery*. 1st ed. Tokyo: Springer-Verlag; 2003:496–501.
10. Lim BH, Loh SY. Reconstruction of a posttrauma arthritic distal radioulnar joint by vascularized second metatarsophalangeal joint transfer. *Plast Reconstr Surg.* 2006;117:19e–23e.
11. Ting ZS, Chang TS, Wang TC, et al. Vascular metatarsophalangeal to ankylosed temporomandibular joint replacement. *Ann Plast Surg.* 1985;15:497–500.
12. Bendon CL, Giele HP. Second toe metatarsophalangeal joint transfer for sternoclavicular joint reconstruction. *J Hand Surg Am.* 2014;39:1327–1332.
13. Roux JL. Radiocarpal reconstruction by island transfer of distal radio-ulnar joint. *Chir Main.* 2010;29:S119–S126.
14. Vilkki SK, Paavilainen P. Vascularized second metatarsophalangeal joint transfer for radial deficiency—an update. *J Hand Surg Eur Vol.* 2018;43:907–918.
15. Kane PM, Vopat BG, Mansuripur PK, et al. Relative contributions of the midcarpal and radiocarpal joints to dart-thrower's motion at the wrist. *J Hand Surg Am.* 2018;43:234–240.
16. Palmer AK, Werner FW, Murphy D, et al. Functional wrist motion: a biomechanical study. *J Hand Surg Am.* 1985;10:39–46.