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Distal Radio-Ulnar Joint Reconstruction after failed Darrach operation using free autogenous second toe Metatarso-phalangeal joint transfer. Development of the technique and a long-term (over 25 year) follow-up

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ABSTRACT

During the development of microvascular surgery in 1980-95 many new methods to overcome different traumatic disorders were studied. Previously unsolved problems could be treated using free tissue transfer. Typical problems in wrist surgery were the painful complications from ulna head resection. No sound or acceptable artificial protheses for ulna head were available. Author did study the possibilities of reversal of resected ulna head using an autogenous microvascular joint transfer. First it was done using cadaver models and evaluating the possibilities of a toe MTP-II joint in replacing the distal radio-ulnar joint. Then same principle was used in three clinical cases. All patients had suffered a poor result after ulna head resection or Darrach procedure. First two cases had complications but third case from year 1994 resulted in a good outcome. This paper introduces the development of a surgical technique for the replacement of the resected ulna head. Also, it will describe the excellent long-term result achieved in the last case with 26-year follow-up. Although today many sophisticated prosthetic replacement techniques have become developed for this purpose, this kind of autogenous reconstruction might have a place in treating similar problems in young posttraumatic patients. Also it demonstrates the potential benefit of microsurgery in a difficult wrist problem.

Introduction

Posttraumatic arthrosis or instability at distal radio-ulnar joint (DRUJ) may develop after common fractures or dislocations around the wrist. Typical malalignment of a radius fracture is a radius shortening with related ulna + deformity. Associated secondary instability is a common reason to pains, discomfort and inability to use the hand forcefully [1]. Historically, that problem has been treated using a short or a modified resection of ulna head (Darrach procedure, Bowers procedure or Sauve-Kapandji procedure). All these resections are leaving some instability and persistent pains are found in over 25% even in recent well studied series [2]. If the shortening is too aggressive, that may easily induce a major iatrogenic instability between distal radius and remaining distal ulna shaft leading to a severe impingement. Sometimes ulna head has been used as a bone graft for wrist arthrodesis. That was formerly accepted in rheumatoid surgery. However, it was not an acceptable method in posttraumatic conditions requiring a wrist arthrodesis. Lack of an anatomic ulnar head without a normal joint surface diminishes the distance between the forearm bones and is a common cause of impingement with associated instability, decreased pronation-supination function, and pain [3]. A patient who has lost the incongruity and stabilizing function of the DRUJ is a difficult management problem. To overcome the problem and to treat severe DRU-joint instability many types of total or partial prostheses [4,5,6] for ulna head and distal radio-ulnar joint have been developed during last 25 years. Fortunately, they are relatively successful, but ideally for young patients biologic alternatives would be preferable to avoid long-term need of complex implants. Autogenic joint transfers [7] have been used in many hand joints since the microsurgical techniques were developed. Even in growing children the reconstruction of congenital radial longitudinal deficiency in order to stabilize the wrist has been done using MTP II-joint transfer [8, 9]. The attempts at autogenic DRU-joint reconstruction using microsurgical joint transfer have been rare in

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Table 1
Comparison of DRU and MTP-II joints.

	DRU-joint	MTP-II joint
size and shape	OK	OK
range of motion	150 degrees (pronation +supination)	150 degrees (45 flexion + 105 extension)
ligaments	centred to ulna axis	centred to ulna axis (MT-head on ulna axis)
good stability	at endpoints	in flexion
instability	in neutral position	in hyperextension
non-constrained gliding	in neutral position	in hyperextension

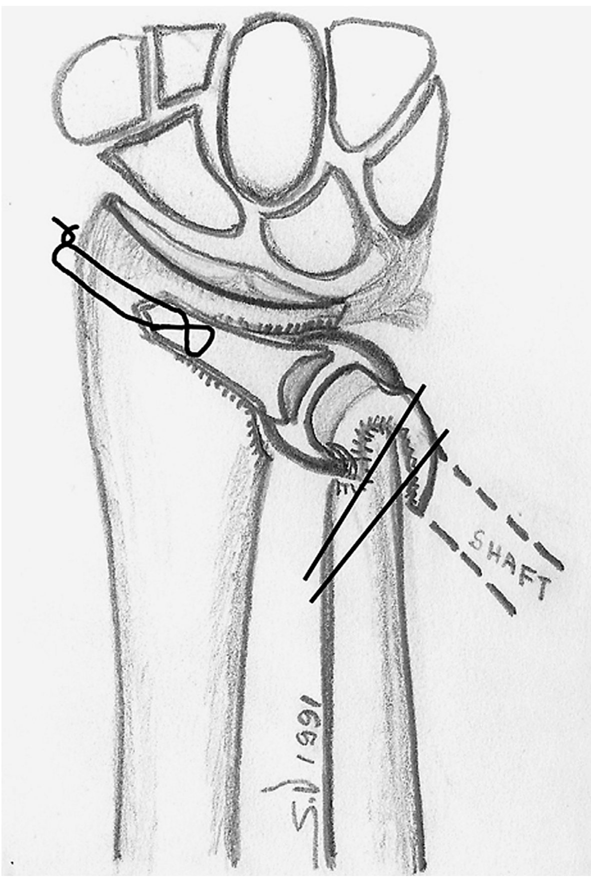

Fig. 1. Original plan for DRUJ reconstruction with an MTP-II joint graft.

literature [10,11,12]. As microvascular joint graft, the MTP II- joint has many characteristics also suitable for DRU-joint reconstruction. The size and curvature of the joint surface of an MT-II head are largely comparable with an ulnar head.

Material and Methods

Cadaver experiments with donor and recipient joint comparison

The aim of study was to create an anatomical reconstruction model (Fig. 1) for the resected ulnar head as a new salvage procedure for failure cases after Darrach procedure. Before clinical attempts, the reconstruction model was tested in six fresh cadaver wrists and the suitability of an MTP–joint in distal radio-ulnar joint replacement was evaluated. Positioning of the new joint and osteosynthesis technique were tested. Necessary microsurgical vascular reconstruction was designed. When comparing an MTP-joint of a second toe and a distal radio-ulnar joint certain similarity can be found (Fig. 2). The joint size, shape and the movement arches of articular joint surfaces are quite similar. There are also clear differences especially in the ligamentous structures (Table 1). In distal radio-ulnar joint some non-constrained gliding can be found when pro-supination is in neutral. Similar gliding or instability is possible when MTP-II joint is in clear hyperextension. A free MTP- joint can be brought into 45-60-degree flexion and it can extend over 90 degrees and reaches a hyperextension of 120 degrees. It is stable in flexion and less stable in hyperextension. This can theoretically allow over 150-degree total motion and provide necessary pro-supination range.

Description of operative technique

Two team approach will shorten the operative time. At wrist the shaft of resected ulna was exposed and freshened. Extensor carpi ulnaris tendon and dorsal branch of ulnar nerve and flexor carpi ulnaris tendon with main ulnar nerve and artery were carefully preserved. A large whole was drilled at Sigmoid notch area and enlarged for proximal phalanx of the joint-graft. About twelve mm diameter hole is necessary and the proximal phalanx portion of the graft is pulled into bone tunnel using cerclage wire. The ends of the wire are pulled through two holes in opposite cortex of the radius and fixed through a small incision radially (Fig. 3a). The goal was to position the proximal phalanx joint surface at the original level of sigmoid notch cartilage surface. The overall alignment of the joint graft was positioned plantar side towards volar direction to simulate original DRU-joint in order to allow necessary range of pro-supination. The metatarsal head (tibial side proximally) was fixed with cerclage and K-wires sideways against the resected surface of distal ulna. Due to a limited flexion ability of toe joint, the flexion of toe was adjusted primarily into 30-degree hyperextension when pro-supination at forearm is kept neutral (Fig. 3a and b). Then during the pronation, the MTP-joint will first turn 30 degrees to reach neutral position of MTP-joint and then additionally about 45 degrees to maximum pronation. In this position the MTP- joint was found to be most stable during cadaver studies. Total range of pronation will be about 75 degrees. Similarly, when forearm is turned into supination the MTP-joint is moving from 30-degree hyperextension to 105 degrees hyperextension and the range of supination is about 75 degrees. The theoretical motion arches have been demonstrated in the Fig. 3b.

Ipsilateral foot was selected as a donor. Second toe was prepared as in normal toe-to-hand transfer. The microsurgical preparation was also done. Donor and recipient vessels were identified. Necessary vessels (Fig 4a) for microvascular anastomoses were taken with the graft, also two dorsal nerves of the toe were included. At recipient site, branches of ulnar artery near the wrist can be used for end-to-end anastomosis or alternatively direct end-to-side anastomosis with ulnar artery can be selected. The distal and middle phalanxes of the toe were discarded and the skin of the toe skin was filleted to act as a covering flap for postoperative monitoring.

Patients and the start of clinical operations

Findings in cadaveric experiments were considered sufficient to allow testing the method in severely handicapped patients. Also,

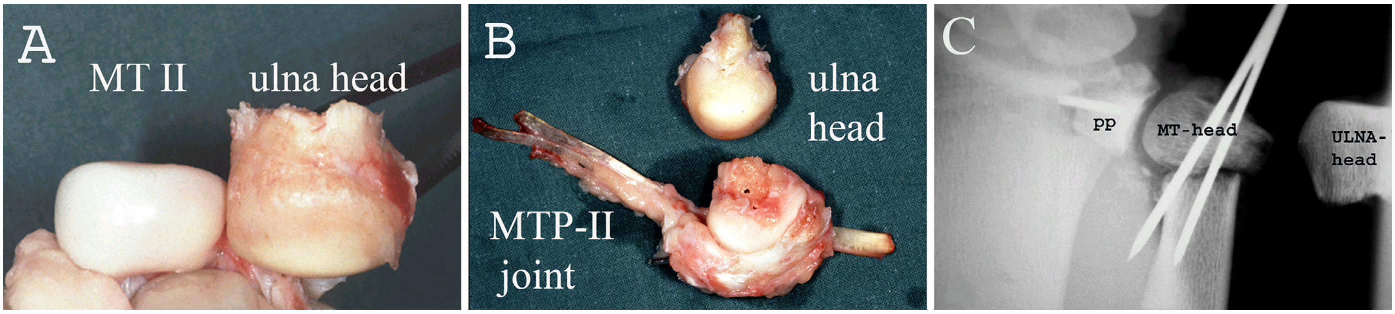

Fig. 2. Cadaveric comparison of the metatarsal-II head and caput ulnae in two planes. (a) sagittal view, (b) side view. Observe the thick plantar plate of the MTP-joint, (c) X-ray view of a cadaver wrist, where ulna head is removed and replaced with autogenous joint graft. (pp= part of proximal phalanx fixed into a whole at sigmoid notch, MT-head = metatarsal head sideways against ulna shaft, *ulna head* at the right side removed from the same wrist for comparison.

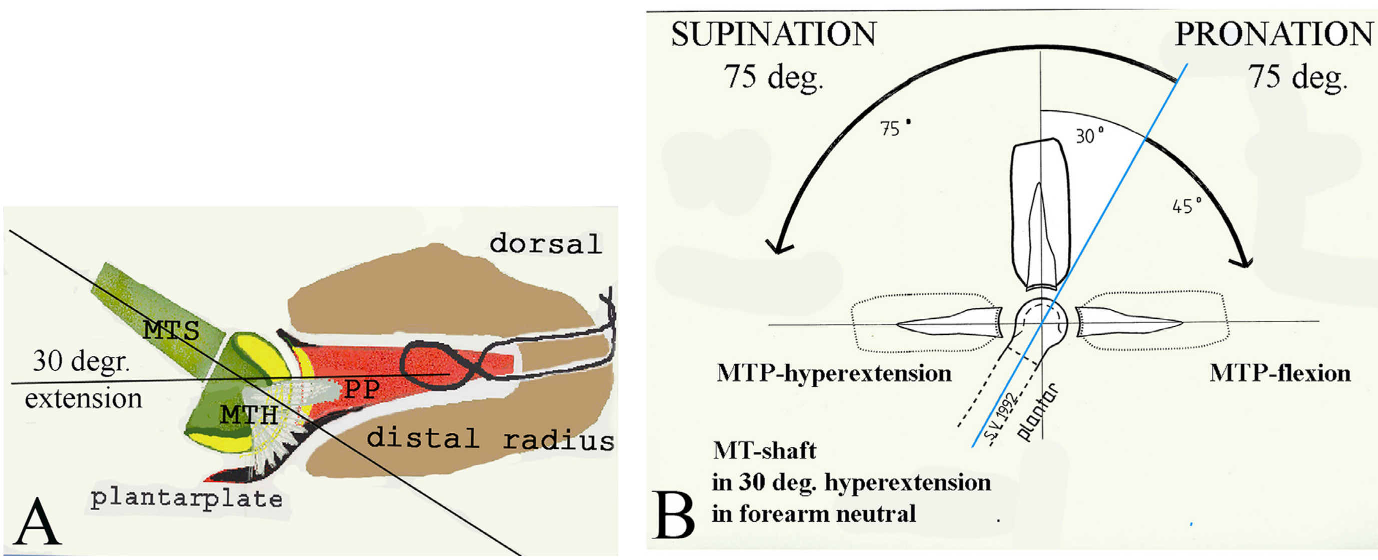

Fig. 3. (a) Position of the transferred MTP-II joint when forearm pro-supination is in neutral position. Metatarsal head should be fixed to distal ulna when the joint is in 30-degree hyperextension in order to allow enough pronation. (MTS = metatarsal shaft which will be removed, MTH = metatarsal head, PP = proximal phalanx). Observe the used osteosynthesis of the proximal phalanx inside the radius. (b) Theoretical range of motion is allowing at least 75 degrees of pronation and 75 degrees of supination.

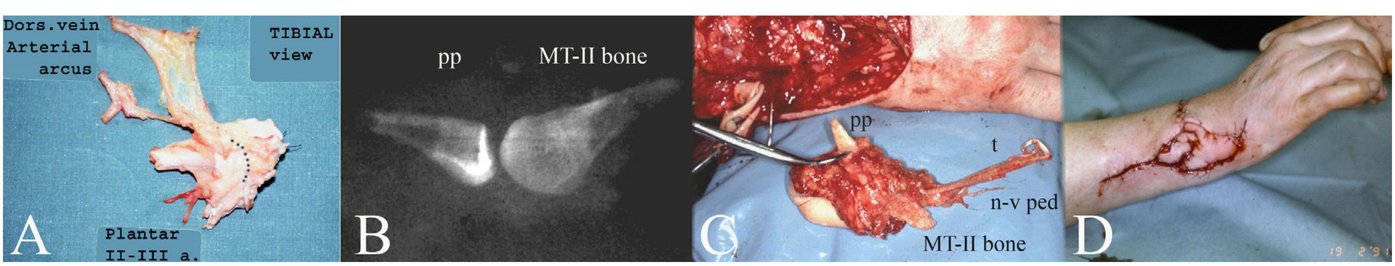

Fig 4. (a) An MTP-II joint graft without skin showing necessary vascular elements. Observe the broad fat layer between the dorsal vein branches for initial coverage. **(b, d, c)** *First clinical case 1991.* (b) X-ray demonstrating the bones and the joint in the graft. (MT-II bone = Metatarsal part of the graft. pp = proximal phalanx part of the graft). (c) The free prepared joint graft at operation (MT-II bone = Metatarsal part of the graft. pp = proximal phalanx part of the graft, n-v ped = neurovascular pedicle including two arteries, vein and two dorsal nerves, t = tendons). (d) monitoring skin island with a good circulation at the end of operation.

experience with toe- and joint transfers treating traumatic and congenital amputations had become a routine with high success rates [13]. Additionally, these operations were considered safe despite of the fact that a very long operative time was needed in complex free tissue transfer. For patient safety, special anaesthesia combinations (brachial plexus and spinal blocks, and epidural anaesthesia) were used to allow the patient to be awake or under mild sedation during the lengthy twelve hour procedure [14].

Patients

There have been three candidates for the reconstruction. The failed ulnar head resection procedures were due to excessive resection, inadequate ligamentous reconstruction or bone graft selection. All patients were continuously painful and unable to use their hands because of major instability and related impingement.

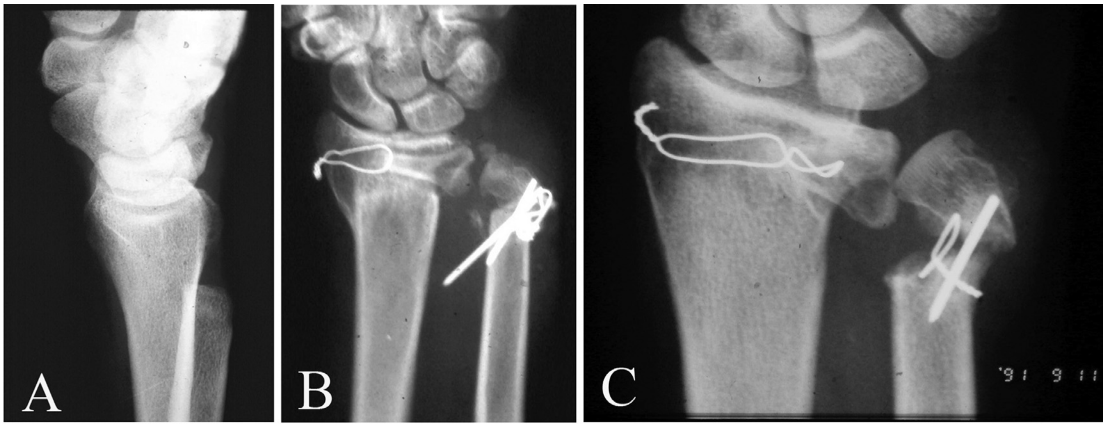

Fig. 5. Case 1. X-ray series of the first patient, a 54-year old female. (a) Preoperative x-ray in side view showing a too wide resection and lack of ulna head with instable distal ulna, (b) X-ray one month after MTP-II joint transfer. (c) X-ray 14 months postoperatively showing non-union between MT-head and ulna. Clearly worsened, alignment and subluxation of the MT-head.

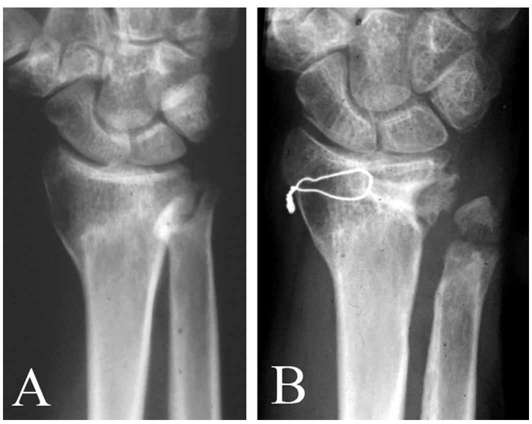

Fig. 6. Case 2. A 51-year old female. (a) Preoperative x-ray. (b) X-ray 13 months postoperatively. The graft with vascular failure has partly absorbed. No healing between MT-head and ulna.

First two less successful cases

The first clinical patient (54 year old female) had a distal right-sided radial fracture which remained painful after primary treatment. An ulnar plus deformity existed which was treated with a Darrach type ulnar head resection. She remained continuously painful with distal radio-ulnar instability. Additionally, she had ruptures of the three ulnar finger extensor tendons. The patient accepted a new proposal about autogenous joint transfer. The first clinical reconstruction of distal radio-ulnar joint (Fig. 4 b, c, d) was done in February 1991. Although the transfer was initially successful (Fig. 5), a non-union of the MT-head with the distal ulna occurred. At one year follow-up the new caput ulnae or metatarsal head was tilted in the radiograph (Fig. 5c) and crepitation and pain persisted. A correction of the pseudarthrosis was done with a bone graft transfer in April 1992. The result proved unsatisfactory in the long-term, perhaps due to joint mal-alignment even though union occurred. The second clinical attempt of distal radio-ulnar joint reconstruction in September 1991 was not successful, perhaps related to arteriosclerotic graft vessels and the patient was a heavy smoker.

Revascularization was not achieved, and the graft did not survive and spontaneously absorbed (Fig. 6). The symptoms returned comparable to a post-Darrach resection in the long-term with continuous instability (Fig. 6). Patient selection failed in this case.

Successful third case

Third clinical case was performed in May1994. The patient was a 50-year old man with earlier (1987) dominant right-sided wrist trauma (luxation of lunate bone). Thereafter he developed a post-traumatic arthrosis secondary to a scapho-lunate advanced collapse (a SLAC wrist) which had been treated in 1993 in another hospital by incorporating the ulna head in a wrist arthrodesis. A major instability and painful impingement occurred between the remaining distal ulna and the radius.

To overcome that iatrogenic complication, we performed a microsurgical autogenous MTP-II joint transfer for reconstruction of the DRU-joint to reverse the post-Darrach type situation (Fig. 7a). That operation and early healing were uneventful. Microsurgical reconstruction consisted of anastomosing two carpal branches of ulnar artery with first dorsal metatarsal artery (I DMTA) and second-third plantar artery at the graft (II/III PMTA) and connecting the dorsal vein of the graft with a concomitant vein of the ulnar artery. Additionally, two dorsal nerves of joint graft were connected to a half of the dorsal ulnar branch of the ulnar nerve. To enforce the ulnar ligament system, the extensor tendons of the graft were pulled distally through the ECU tendon and fixed near its insertion. Osteosynthesis between metatarsal head and distal ulna was done with cerclage and K-wires. Additional bone received from radius tunnel, which was carved to accommodate the proximal phalanx into distal radius, was used to ensure the bony union between metatarsal head and distal ulna. Overall alignment of the joint-graft differed about 25 degrees from the transverse line (Fig. 7b). Postoperatively the joint slowly incorporated to its place (Fig. 7c, d) without complications. He recovered and the function improved and a good stability was achieved at his neo-DRU-joint. Also, the pro-supination movement returned to good values. The patient has been followed regularly now over 26 years and the result has been successful and the patient has continuously been very satisfied with his reconstructed wrist. The wrist has limitations due to previous radiocarpal arthrodesis but as far as DRU-joint function is concerned, this reconstruction with autogenous joint transfer has fulfilled patient's expectations (Fig. 8). The measured pronation 70/80 (right/left) and supination 60/90 (right/left) will allow good use of the hand. Patient has been able to use the hand in heavy building work using modern electrical tools. However, he is unable to use a hammer or a traditional screw driver but that may be partially due to the stiff wrist. The radiographs show solid union of the II MT head to the ulna and maintained metatarso-phalangeal joint space at 25 years post operatively (Fig. 9). Finger motions and hand power are in normal

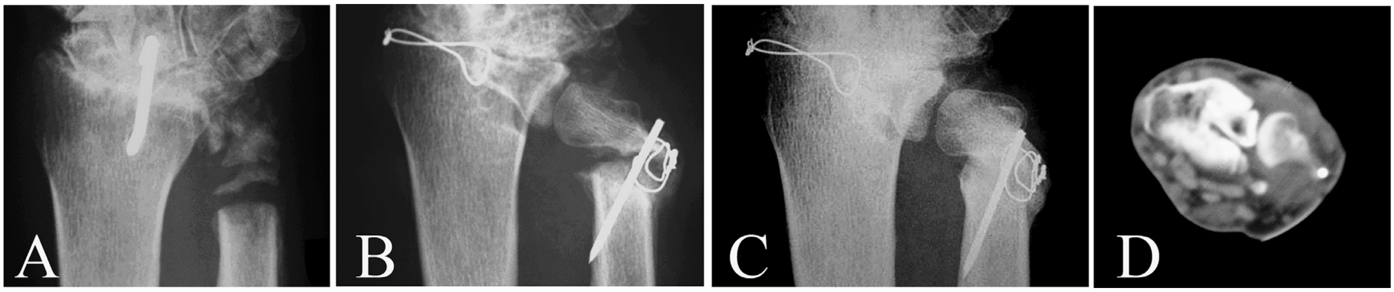

Fig 7. Case 3. 50-year old male. Operated in May 1994. (a) Preoperative X-ray. Caput ulna had been used as a bone graft for wrist arthrodesis one year earlier. (b) Early (1 month) postoperative X-ray showing a good alignment of the MTP-II graft as neo-DRU-joint. (c) X-ray at 1-year postoperatively. Joint transfer is well integrated to its place. (d) CT-scan at neo-DRU-joint level taken in semi pronated position 9 months postoperatively. Healthy articular contacts can be seen between metatarsal and proximal phalanx.

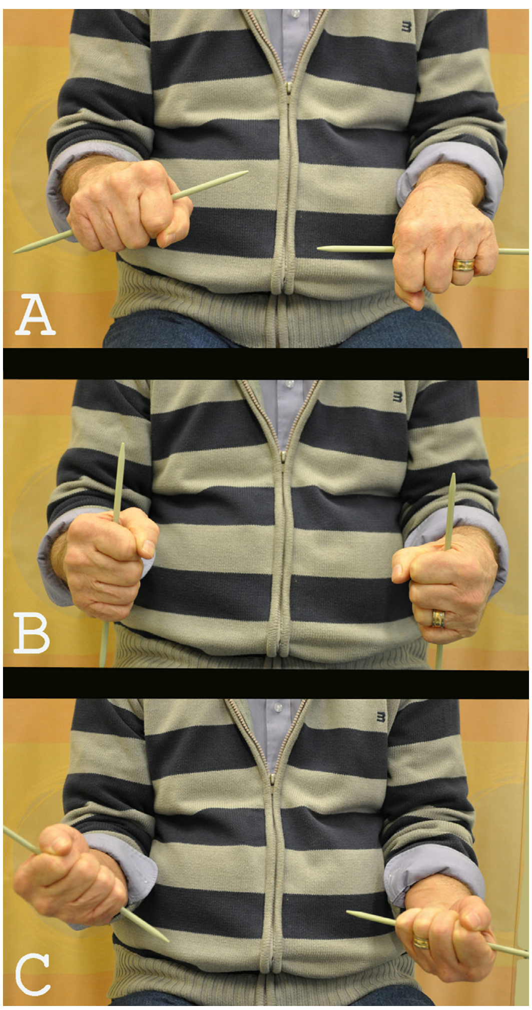

Fig 8. Case 3. Clinical views 20-years after operation. Subjectively the patient has a good range of motion in the right operated wrist and the wrist feels stable during the pro-supination. Right forearm pro-supination from 70-degree pronation to 60-degree supination. No pains or discomfort
(a) in maximal pronation
(b) in neutral
(c) in maximal supination.

range. Jamar grip 26/24 kg (right/left). His score in December 2020 in Patient-related Wrist evaluation (PREW) was 12 points. Also test result using the Quick DASH was 11,4 points. He has had no complaints at donor foot after the first postoperative year.

Discussion

Huge development has occurred in understanding the physio mechanics of DRU-joint during last three decades. The painful pro-supination of forearm and impingement between instable distal ulna stump and radius has been one of the great problems after Darrach and Sauve-Capandji procedures used in the treatment of ulnar wrist pain [15]. Modern DRU-joint arthroplasty techniques, in form of total or partial distal radio-ulnar joint replacement [16,17,18] as a salvage of failed Darrach or Sauve-Capandji operations, have shown acceptable results [19,20,21,22,23] even in longer follow-ups. The last-mentioned systematic study [23] shows data from 29 published papers and the meta-analysis has a 28% overall complication rate. The life span of a metallic prosthesis may be limited and a similar need for reconstruction in younger patient groups may be an indication to search and study autogenic and biologic options also in DRU-joint reconstruction. Developing a new complex reconstructive procedure needs careful planning, comparison of anatomy and understanding the function of donor and recipient sites. Model operations and biomechanical evaluation using cadaver wrist must proceed all new clinically performed techniques [24, 25]. Also, long-term follow-up postoperatively is necessary to judge the value of new reconstructive procedure. Additionally, in this type complex reconstruction (autogenous graft for any joint reconstruction) needs perfect co-operation between patient and treating surgeon. There is always a donor site, which potentially may cause problems postoperatively. Toe transfers have been our routine procedures over 40-years and donor site problems have been rare [26]. Today the experience with toe-joint transfers has increased for example in the treatment of congenital hand anomalies [27] and is related with similar planning. The described three DRU-joint reconstructions with autogenous MTP-joint graft were performed just before the time when many new prosthetic implants to correct radio-ulnar instability or lack of the ulna head at the wrist appeared and were considered as sustainable and easily reproducible options. This study has several limitations. The number of clinical cases is small mainly because prosthetic replacement of the ulna head or whole radio-ulnar joint became more attractive and less time-consuming. Also, the knowledge in treating common injuries at the wrist generally improved and ulna head resections became less popular. The difficulties in first two cases are representing the steps included in the development of a new technique. The present paper is written retrospectively with the informative aim that also biologic solutions may work in experienced microsurgical centres. This is important when reconstruction is needed for young patient. Although only one excellent long-term result was achieved, the paper is introducing a new technique and its development.

Fig 9. Case 3, X-ray series in long time follow-up over 25 years
(a) 5 years postoperatively
(b) 11 years postoperatively
(c) 20 years postoperatively
(d) 25 years postoperatively

Conclusion

The described biologic alternative for distal radio-ulnar reconstruction in failed Darrach cases has been developed and its feasibility confirmed. Microsurgical joint replacement is always demanding and therefore, this type of reconstruction is suitable only in centres with competent microsurgical teams together with wrist specialists. Despite the many prosthetic alternatives, a biologic alternative potentially offers another choice in young trauma patients. The procedure is technically difficult and precise alignment of the fixation is critical. Newer fixation techniques should aid in obtaining bone union.

Declarations of interest

None.

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