Hand Surgery and Rehabilitation 38 (2019) 150–156

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Original article

Results of wrist hemiarthroplasty for comminuted distal radius fractures in independent elderly people: A retrospective study on eleven patients

Résultats de l'hémiarthroplastie de poignet dans les fractures complexes de l'extrémité distale du radius chez la personne âgée autonome : une étude rétrospective sur onze patients

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ARTICLE INFO

Article history:
Received 15 March 2018
Received in revised form 29 September 2018
Accepted 30 November 2018
Available online 1 February 2019

Keywords:
Distal radius fractures
Resurfacing prothesis
Hemiarthroplasty
Elderly patients

Mots clés :
Fractures du radius distal
Prothèse de resurfaçage
Hémiarthroplastie
Sujet âgé

ABSTRACT

The comminuted distal radius fractures among elderly people are usually linked to osteoporosis, and repairing them in this context is a therapeutical challenge. Several teams have reported good results of radius resurfacing. The goal of our study was to evaluate the usability of the wrist in a new series of patients after surgery. We performed a monocentric retrospective study on the data of the medical files. All the included patients were older than 65 years and received a wrist hemiarthroplasty according to the criteria that have been established by the in charge medical team. Eleven patients have been included, their average age was 80.4 years old, and the average follow-up was 18.3 months. The average QuickDASH Score was 59 (27–95). The Visual Analogue Scale for pain was in average 3.8/10 and the average mobility was: flexion 36° (12–50), extension 27° (12–50), radial deviation 15° (12–15), ulnar deviation 26° (12–40), pronation-supination range of motion 164° (150–170). The average measured strength was 44% (16–72%) of the strength of the unaffected hand. Our results are rather modest, probably because of insufficient follow-up and very severe fractures. Furthermore, the implant that has been used does not take into account the distal radioulnar joint. Another bound of this treatment is the complexity of surgical revision in case of bad result. So far, hemiarthroplasty cannot be considered as the standard treatment for complex fractures of the distal radius.

RÉSUMÉ

Les fractures comminutives de l'extrémité distale du radius (EDR) chez la personne âgée sont souvent liées à l'ostéoporose, et leur réparation dans ce contexte est un défi thérapeutique. Quelques équipes ont décrit de bons résultats du resurfaçage du radius. L'objectif de notre étude était d'évaluer la fonction des poignets d'une nouvelle série de patients. Nous avons réalisé une étude rétrospective monocentrique sur les données des dossiers médicaux. Les patients inclus étaient tous les patients de plus de 65 ans ayant bénéficié d'une hémiarthroplastie de poignet selon les critères établis dans le service. Onze patients ont été inclus, d'un âge moyen de 80,4 ans avec un recul moyen de 18,3 mois. Le score QuickDASH moyen était de 59 (27–95). L'échelle visuelle analogique de la douleur étaient en moyenne à 3,8/10 et les mobilités moyennes étaient : flexion 36° (12–50), extension 27° (12–50), inclinaison radiale 15° (12–15), inclinaison ulnaire 26° (12–40), arc de pronation-supination 164° (150–170). La force moyenne mesurée

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https://doi.org/10.1016/j.hansur.2018.11.004
2468-1229/

était à 44% (16–72) de celle du côté opposé. Nos résultats sont modestes, probablement en raison d'un recul insuffisant et d'une importante gravité des fractures. L'implant utilisé ne prend en outre pas en compte les lésions de l'articulation radio-ulnaire distale. Une autre limite de ce traitement est la difficulté d'une reprise chirurgicale en cas de mauvais résultat. Pour l'heure, l'hémiarthroplastie ne peut être considérée comme le traitement de référence des fractures complexes de l'EDR.

1. Introduction

Distal radius [DR] fractures are one of the most frequent fractures in adults [1] and also occur most often due to osteoporosis. This increases both comminution and the complexity of two elements of surgical treatment: anatomical reduction and osteosynthesis stability. As outlined by Herzberg and Dumontier in their "analysis method", the first data to be analysed in the case of a DR fracture is the patient environment [2,3]. Bedridden patients tolerate malunion [4], but treatment of complex epiphysary fractures in autonomous elderly patients is a therapeutic challenge. The type of fracture must also be considered. Lafontaine et al. described five factors to predict instability in the case of orthopaedic treatment: an age of 60 years or more, a radial slope in the sagittal plane with dorsal angulation of over 20°, dorsal comminution, intra-articular damage and an associated ulna fracture. If there were more than two of these factors combined, the risk of secondary displacement was significant [5]. Judet et al. also described comminuted fractures as contraindications to orthopaedic treatment [6]. Intrafocal pinning as described by Kapandji no longer has a place in articular fractures [7]. If combined with additional osteosynthesis only, external fixator treatment could correct the collapse of a comminuted fracture source [8,9] with however a strong rate of complications (primarily infections and lesions of the sensory nerve branches) [10]. Posterior plates were created to counteract the inadequacies of osteosynthesis through pins and external fixation [11]. They are based on two principles. "Console" plates are opposed to posterior movement [12], and "column" plates reconstruct the DR anatomy into two columns: radial and ulnar [13]. The complications were close to 30%. The size of these plates and the systematic lesion of the Lister's tubercle had an impact on the nerves and tendons, particularly on the extensor pollicis longus tendon [14]. The comminution above, often associated with posterior displacement fractures, has led to the description of a volar plate supplemented by posterior intrafocal pinning, combining anterior and posterior osteosynthesis [15]. Orbay and Fernandez have also described osteosynthesis of the anterior cortex as the most resistant [16]. Anterior plate osteosynthesis is currently the most used technique. Filling of the post-reductional hole by a transplant or bone substitute must sometimes be combined with this synthesis [17].

Roux put forward the idea of replacing the DR with a prosthesis [18]. This is a well known concept in orthopaedics, and has already been used on the hip [19], shoulder [20], knee [21] and elbow [22]. Total wrist prostheses, used in the treatment of rheumatoid arthritis or post-traumatic arthrosis, do not have satisfactory long term results, but this is generally due to failure of the carpal implants [23,24]. Roux carried out the first set of DR hemiarthroplasties for complex epiphysary fractures on autonomous elderly patients [25], followed by three other teams [26–28].

The main objective of our study was to evaluate wrist function in patients who underwent wrist hemiarthroplasty operations in our centre, following the recommendations of these teams. The secondary objectives were to evaluate mobilities of the operated wrists, as well strength, pain and occurrence of complications. We evaluated the prevalence of type 1 complex regional pain syndromes (CRPS), displacement and prosthetic loosening.

2. Methods

2.1. Definition of the study

This was a retrospective study conducted outside of human research, based on data from medical files.

The inclusion criteria were: an age over 65 years, autonomy defined by the patient living at home and not requiring help with activities of daily living, and a history of a resurfacing RD Cobra® prosthesis (Lépine™, Lyon, France), placed by our team between 2016 and 2017. Eleven patients met this criteria. They were all included in the study.

Wrist function was evaluated by collecting QuickDASH functional method score results (Disabilities of the Arm, Shoulder and Hand), PRWE (Patient Rated Wrist Evaluation) Scores and Lyon Wrist Scores, in the framework of current practice. The first is the Functional Reference Score for the upper limb, and it has been validated for DR fractures [29]. The others are specifically aimed at the wrist. We wanted to use these three scores, which are used in other wrist hemiarthroplasty studies, in order to better compare the data [18,25–28]. The Lyon Score, described by Herzberg, allows pronation-supination measurements to be included [30].

Mobilities and strength were evaluated using data collection from clinical exams. Mobilities had been measured using a goniometer, and strength using a Jamar hydraulic hand dynamometer.

The pain was evaluated by the Visual Analogue Scale (VAS) in the framework of current monitoring. This ranged from 0 (non-existent pain) to 10 (maximum pain).

The type 1 CRPS rate was defined by the ratio between the number of type 1 CRPS collected and the total number of patients.

The occurrence of a displacement or loosening was evaluated through analysis of simple frontal and lateral radiography carried out during patient monitoring.

The pre-operative planning required simple frontal and lateral radiography of the wrist, as well as a systematic scan, with three dimensional reconstructions. The reinterpretation of these images from medical files allowed for characterisation of the fractures according to the Osteosynthesis Association (AO) and Laulan classification: Metaphysis Epiphysis Ulna (MEU) [31]. We have used the AO classification because it is internationally recognised. The MEU classification is more reproducible and more relevant, because it has a therapeutic and prognostic value [32].

2.2. Surgical technique

The patients were operated either under general anaesthetic [GA], or loco-regional anaesthetic (LRA) by axillary block. The anaesthetist decided this based on their own habits and the patient's history and wishes. The patient was put in the dorsal decubitus position, with the operated upper limb placed on a radio-transparent arm table, with an inflated tourniquet at the root.

Table 1
Patient characteristics.

Patient	Sex	Age (years)	AO Classification	MEU Classification	Dominant side	Broken side	Time before surgery (d)	Anesthesia	Cementing	Operating time (min)	Associated actions	Hindsight (months)
1	F	85	C3	M4'E4U2	R	L	3	LRA	No	40		21
2	F	73	C2	M3'E3U1	R	R	2	LRA	No	55	Darrach after 6 months	20
3	F	89	C3	M3'E3U0	R	L	2	LRA	No	60		20
4	F	65	C3	M4'E4U2	R	L	3	LRA	Yes	45		19
5	F	80	C2	M3E3U3	R	R	3	GA	Yes	60		19
6	F	83	C3	M4'E4U2	R	R	1	GA	Yes	60		19
7	F	91	C3	M2'E3U1	R	L	4	GA	Yes	50		18
8	F	72	C3	M3'E3U4	R	L	2	GA	Yes	75	Darrach	17
9	F	85	C3	M4'E4U4	R	R	1	GA	Yes	70	Darrach	17
10	F	81	C3	M4'E4U2	R	R	3	GA	Yes	55		16
11	F	80	C3	M4'E4U1	R	R	2	LRA	Yes	50		15

F: female; AO: association for osteosynthesis; MEU: metaphysis epiphysis ulna; D: day; Min: minute; R: right; L: left; GA: general anesthesia; LRA: local-regional anesthesia.

The wrist approach was dorsal in italic S shape, in the axis of the third finger, on 6 to 8 cm. The dorsal venous network was carefully preserved. The extensor retinacula was open at the third compartment. Sub-capsular-periosteal detachment was carried out with a cold knife technique. The posterior interosseous nerve was then electro-coagulated. After exposure of the joint space, the epiphysary bone fragments were resected with a Gouge clamp. This resection was limited to preserve the peri-prosthetic bone stock. If there was an associated fracture of the ulnar head, this was resected. Reaming of the radial medullary was carried out in the axis of the third metacarpal, starting with a bone awl then using an ancillary reamer, in increasing sizes. An intra-operative fluroscopic check was carried out on the trial implant, in order to check correct positioning, and above all the correct height of the implant. The final implant may or may not be cemented, depending on the primary stability. If there is major bone loss, a bone transplant may be used. The final testing must conclude with good joint stability and a piston of 2 mm. Closure was carried out in three planes: the periosteum, the retinaculum and the skin, on an wound suction unit.

The patients were then immobilised for three weeks with a below elbow cast, before starting physiotherapy.

Normal radio-clinical monitoring was carried out at 3 weeks, 6 weeks, 3 months, 6 months, 1 year and then once per year. Some patients were reviewed more frequently if their clinical status required this.

2.3. Legal framework

The study was approved by the Ethics and Clinical Experimentation Committee in our hospital on 30 January 2018. It was carried out according to the MR-003 reference methodology of the French National Commission for Data Protection and Liberties (CNIL). The patients received information by a letter sent to their home informing them that unless they were opposed, the data in their medical file could be used for this study. None of the patients were opposed to this. The data was processed on a secure hospital computer which was not connected to the internet and It was not removed from this location. It was not sent to third parties.

3. Results

3.1. Patient characteristics

All of the patients were women (Table 1). The average age was 80.4 years (65–91) at the time of surgery: 55% of operated fractures were on the dominant side, which was always the right.

Nine fractures were classed as C3 (82%) and two were classed as C2 (18%) using the AO classification (Fig. 1). There was systematically a metaphysary comminution, M4 in the MEU classification in 6 patients (56%), M3 in four patients (36%) and M2 in one patient (9%). The radius fracture affected the distal radio-ulnar joint (DRUJ) in 10 patients (91%). An epiphysary comminution was still present: six patients were classed E4 (55%) and five patients were E3 (45%). Three patients had an associated metaphysary ulnar fracture (27%): two U3 and one U4: two had an ulnar head resection (Darrach technique), the last patient did not receive an ulnar manoeuvre as the fracture was not strictly displaced; seven patients had an associated fracture of the ulnar styloid process (U1 and U2) (64%); only one patient had a strictly intact ulna (U0).

All the patients were operated on in the acute phase, and the average duration between the fracture and the surgical treatment was 2.4 days (1–4). It was carried out under GA in six patients (55%) and under LRA in five patients (45%). The average duration of the surgery was 56 minutes (40–75). Eight prostheses (73%) were cemented and three (27%) had a good primary hold which did not require cementing.

The hindsight ranged from 15 to 21 months, with an average hindsight of 18.3 months.

3.2. Clinical results

The average QuickDASH score was 59 (27-95) with $\sigma = 27$ standard deviation, the average PRWE score was 72 (31–118) with $\sigma = 29$ standard deviation, and the average Lyon score was 50% (16-69) with $\sigma = 16$ standard deviation (Fig. 2).

None of the patients claimed to be without pain. Five had slightly bothersome pain, seven were very bothered with pain which at times kept them awake. One patient was woken up every night. The average pain was 3.8/10 (1-8) (Table 2).

The average mobility obtained was: flexion 36° (12–50), extension 27° (12–50), radial deviation 15° (12–15), ulnar deviation 26° (12–40), pronation-supination arc 164° (150–170).

The average strength measured was 44% (16–72%) of that of the opposite side.

Subjectively, seven patients were satisfied or very satisfied with the result. Four were not satisfied.

3.3. Radiographic results

None of the implants were displaced and none had signs of loosening (Fig. 3). No radial or ulnar tilt of the carpus was observed.

3.4. Complications

None of the patients had sepsis. Two suffered type 1 CRPS confirmed by a bone scan, with a prevalence of 18%.

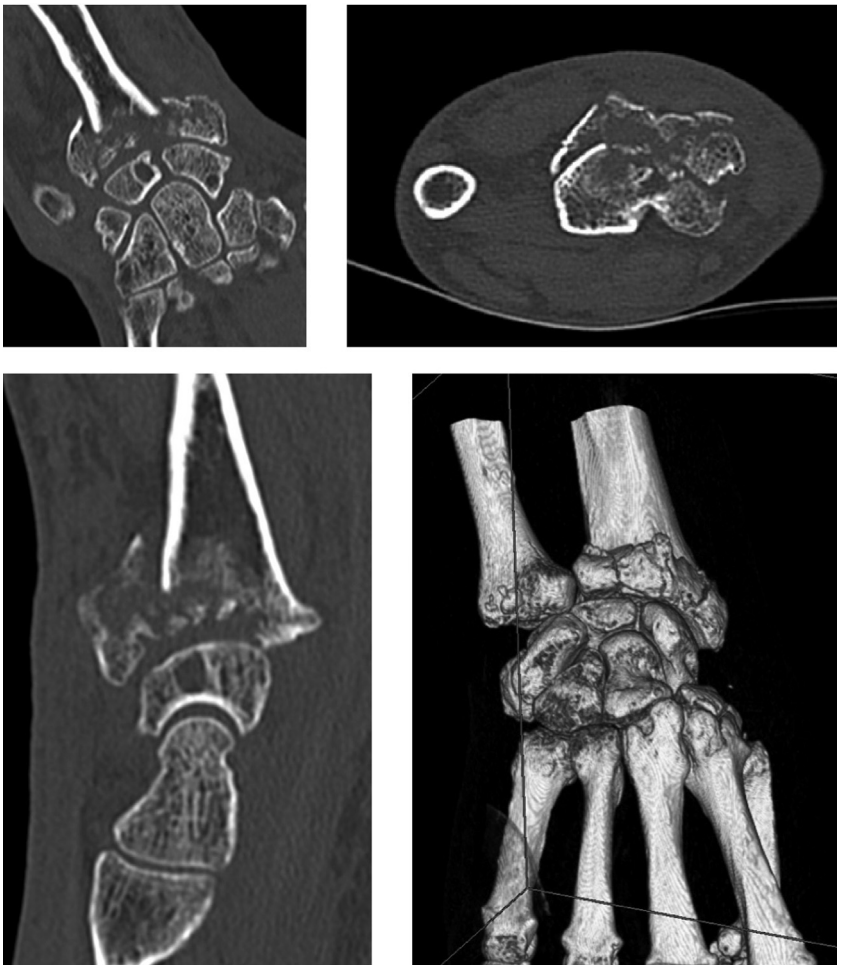

Fig. 1. Pre-operative CT-scan views within the three planes of space, and three-dimensional reconstructions. Viewing of metaphysary and epiphysary comminution in addition to the distal position of the fracture.

One patient was taken in again for a resection of the ulnar head at 6 months, as she presented pronation-supination pain. This did not improve.

4. Discussion

Recent studies showed good wrist hemiarthroplasty results following articular communitive fractures in elderly patients, which opened new treatment perspectives for this frequent pathology, meaning that patients could quickly regain autonomy [25–28]. This technique was interesting, because it allowed the four anatomical parameters of the DR linked to functional prognosis to be corrected [2,3]: the shortening of the radius through metaphysary collapse, inclination of the radial slope in the frontal plane, the inclination of the radial slope in the sagittal plane and the articular impaction.

The patient populations included in our study are comparable to those described in the literature as we have followed the author recommendations. In particular, all were over the age of 65 and autonomous. The fracture characteristics reported in Table 1, are difficult to compare as only one team used a reproducible classification, that of the AO [26]; the others only provided inclusion criteria on severity.

The results from the three functional scores are quite weak: 59 for the average QuickDASH Score, 72 for the average PRWE Score and 50% for the average Lyon score. The standard deviations are very high, which showed great disparity in the results, probably through a lack of power in the study. The range of motions are reduced for flexion-extension (average arc of 63°) but very slightly for radial and ulnar deviations (an average of 15 and 26° respectively) and pronation-supination (average arc of 164°). Strength (9 kg vs.19 kg) and pain (average VAS of 3.8) were the most disabling criteria for patients. These pains cannot be linked to failure of the implant, as the radiological follow-up did not show any loosening. The only complication found, the type 1 CRPS, had quite a low prevalence, 18%, the same as in the literature.

Two anatomical criteria, linked to associated lesions, are not very well controlled with this treatment: there are intra-carpal lesions and DRUJ lesions. Ligament injuries are frequently associated with these types of fractures, but rarely need repair [33]. Laulan and Bismuth have notably shown that a scapholunate lesion does not really mean that this is incompetent, and therefore does not need repair. They diagnosed this in 43% of DR fractures in their set, without any clinical repercussion after one year [34]. We have not found any ligament injury in our set.

The main consequence of DR fractures appears to be due to an DRUJ pathology (pain and/or reduction of pronation-supination) [35]. There is no reliable recommendation concerning ulna lesions. For fractures of the styloid process, the results are not as good in the case of significant displacement [31] and when located at the base [36]. In the absence of DRUJ instability, no functional benefits of fixation have been shown, which pushes towards abstention

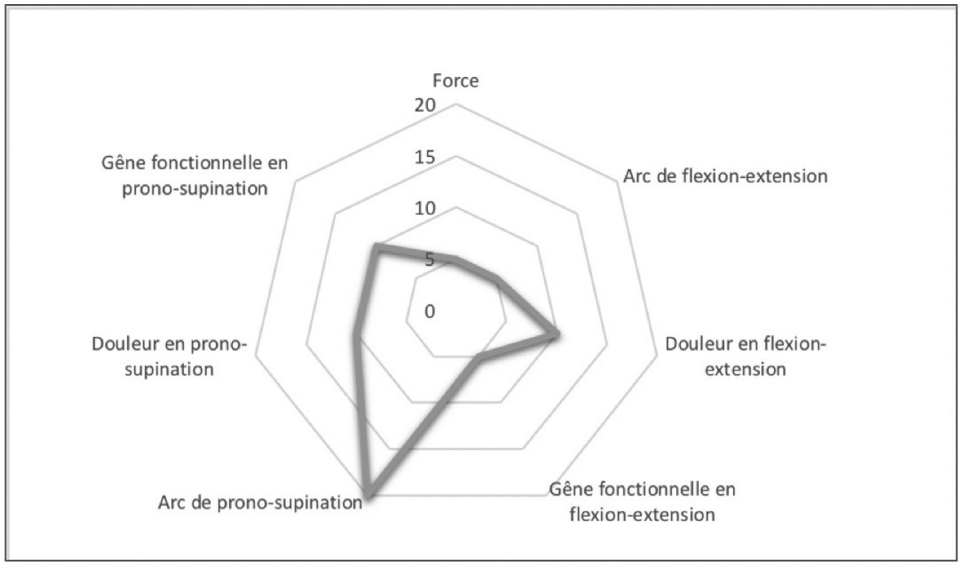

Fig. 2. The average Lyon Score: 0 corresponds to the minimum score for a selected criteria, and 20 to the maximum score.

Table 2
Clinical results.

Patient	Hindsight (months)	VAS for pain	Flexion (°)	Extension (°)	Radial deviation (°)	Ulnar deviation (°)	Pronation-supination (°)	Strength vs contralateral side (kg) (percentage of opposite side)	Complications	PRWE	Quick DASH	Lyon Score (%)
1	21	1	45	25	15	30	170	12 vs. 22 (45%)		50	39	53
2	20	7	40	15	15	20	150	8 vs. 18 (55%)		98	93	38
3	20	4	30	20	15	35	165	9 vs. 16 (56%)		70	56	54
4	19	1	50	50	15	40	170	18 vs. 25 (72%)		47	34	66
5	19	7	30	15	15	20	150	6 vs 18 (33%)		112	91	31
6	19	1	50	30	15	40	170	10 vs. 19 (53%)		43	27	69
7	18	2	30	45	15	15	170	8 vs. 16 (50%)		65	35	63
8	17	8	12	25	12	12	170	4 vs. 20 (20%)		118	95	16
9	17	2	35	30	15	35	170	9 vs 18 (50%)		31	32	66
10	16	3	40	30	15	20	165	8 vs. 18 (44%)	Type 1 CRPS	54	50	54
11	15	6	30	12	15	20	150	3 vs. 19 (16%)	Type 1 CRPS	100	93	41
	18.3	3.8	36	27	15	26	164	9 (44%)	2 type 1 CRPS	72	59	50

VAS: visual analogue scale; CRPS: complex regional pain syndrome; PRWE: patient rated wrist evaluation; DASH: disabilities of the arm, shoulder and hand.

[37]. For fractures of the ulnar neck or head, initial fixation or resection must be discussed. Abstention on the ulna provides good results in elderly patients [38]. We carried out resection of the ulnar head in the case of a displaced fracture of this, and we have not treated styloid fractures, regardless of whether they are displaced or not.

Ten patients (91%) presented an DRUJ lesion, as a fracture line went through ulnar incision of the radius. However, our set did not report any pronation-supination range limitations. It is however possible that an DRUJ lesion contributes to pain.

The resurfacing prosthesis designed by Roux and also used by Vergnenègre, (Sophia®, Biotech™, Nogent, France) is made of a shaft stem and a metaphyso-epiphysary block presenting two joint surfaces: one distal for the carpal condyle and another medial for the ulnar head. The results from the two teams are more or less the same [25,26]. Through its design, this implant resolves the problem of DRUJ lesions. We have placed the same implant as Herzberg [27], the Cobra® prosthesis, designed by the latter, and developed by the Lépine™ laboratory, although with much lower results. The hypothesis that the results could be

Fig. 3. Follow-up X-rays of face and profil of wrist. None of displacement, none of loosening of the implant, none of tilt of the carpus.

Table 3
Results comparison of the different teams.

	Number of patients	Average hindsight (months)	VAS for pain	Flexion-extension arc (°)	Strength (% contralateral side)	Lyon score	PRWE	QuickDASH	Complications
Roux [25]	17	56		99	79%			26	
Vergnenègre and al. [26]	8	25	2	89	90%	78.6%		18.2	1 periprosthetic calcification
Ichihara and al. [28]	11	32	2.8		> 56,2%			37.4	1 revision for resection of the first row of the carpus
Herzberg and al. [27]	11	30	1	60	67%	73%	24	32	3 type 1 CRPS 1 revision for adhesions
Anger and al.	11	18	3.8	63	44%	50%	72	59	2 type 1 CRPS 1 revision by Darrach

VAS: visual analogue scale; CRPS: complex regional pain syndrome; PRWE: patient rated wrist evaluation; DASH: disabilities of the arm, shoulder and hand.

improved by the Cobra® prosthesis version (currently in development) which also replaces the DRUJ, is weakened by the good results of the Lyon team. The material used by Ichihara [28] is a little bit different in its design even though it is an iso-elastic implant (Prothelast®, Argomedical AG™, Cham, Switzerland) with a medullary pin.

Another hypothesis explaining the pain could be the contact between the cartilage surface of the proximal carpal row and the cobalt-chrome (CoCr) alloy of the prosthesis. In total knee prostheses, some authors prescribe carrying out systematic resurfacing of the patella to avoid anterior post-operative pain linked to rubbing of the femoral CoCr implant against the patellar cartilage [39]. Regarding the hip, the invention of the intermediary prosthesis responded to a frequent complication of the Moore prosthesis, cotyloiditis, which resulted from impaction of the vitallium head against the acetabular cartilage [40]. We do not prescribe the totalling of wrist prostheses and we have already insisted on the need for better carpal implant results. However, further reflection on the prosthesis surface material in contact with the joint could be interesting.

Despite these attempts to present our modest results, we are not explaining the differences with the other teams completely (Table 3). This could be due firstly, to a reduced follow-up in our study, but also due to the increased severity of the fractures. Vergnenègre had included patients presenting C2 fractures from the AO classification [26] when we have almost exclusively included C3 fractures. In addition, the Lyon team included patients with "fractures that are more distal than the watershed line" [27], which is logical as the plates must never exceed this distal limit at the risk of becoming intra-articular [35]. In this case, the prosthesis can replace epiphysary comminution and has a good hold of the radial columns. This appears to be a good indication of resurfacing. This data is coherent with the low number of implants needing cementing in this series. Conversely, all of our patients also presented metaphysary comminution.

One of the limitations of this treatment is the complexity of a surgical revision if there is a poor result. Indeed, arthrodesis would need a spongious bone autograft, with a large tricortical transplant, or more probably an allograft due to loss of bone substance due to the material. Totalisation of the prosthesis could be discussed but

total wrist prostheses carried out in other indications have not had very good results either.

This study lacks power due to the small population studied and the fact that it is a retrospective work. Therefore, it has a weak standard of proof. More significant powerful studies must be carried out. It is also necessary to consider biomechanical thinking to improve implants (particularly at the DRUJ) and to refine the indications.

5. Conclusion

The treatment strategy for complex DR fractures in elderly patients must be the subject of a lot of thought. Orthopaedic treatment must be reserved for patients with the lowest functional demands. Autonomous patients must have surgical treatment. If isolated pinning can be excluded, the surgeon must discuss external fixation, plate osteosynthesis and prosthesis resurfacing of the radius, considering the patient, the fracture characteristics and their own habits. None of these treatments have provided excellent results, and hemiarthroplasty cannot claim, for now, to be the treatment of choice. However, it should not be excluded from our therapeutic arsenal, as it does not have a higher rate of complications or poorer results than other techniques.

Disclosure of interest

The authors declare that they have no competing interest.
The prosthesis implanted, Cobra® from Lépine™ laboratory, France was designed by G. Herzberg, Lyon.

References

[1] Court Brown CM, Caesar B. Epidemiology of adult fractures : a review. Injury 2006;37:691–7.
[2] Dumontier C, Herzberg G. Classifications du radius distal. Rev Chir Orthop Reparatrice Appar Mot 2001;87(Suppl:78):85.
[3] Herzberg G, Izem Y, Al Saati M, Plotard F. "PAF" analysis of acute distal radius fractures in adults. Preliminary results. Chir Main 2010;29:231–5.
[4] Saffar P, Mazodier F, Werther JR. Fractures in the elderly patient: is it necessary to operate on patients over 75 years old? Rev Chir Orthop Reparatrice Appar Mot 2001;87:130–2.
[5] Lafontaine M, Delince P, Hardy D, Simons M. Instability of fractures of the lower end of radius : a propos of a series of 167 cases. Acta Orthop Belg 1989;55:203–16.
[6] Judet T, Piriou P, Garreau de Loubresse C, Rouvreau P. Y a-t-il une place pour le traitement orthopédique des fractures de Pouteau-Colles? In: Allieu Y, Roux JL, Meyer zu Reckendorf G, editors. Fractures du radius distal de l'adulte. Montpellier: Sauramps; 2006. p. 51–6.
[7] Terver S, Reig S, Fortunato-Robinot B. Déplacement secondaire des fractures extra et intra articulaires de l'extrémité distale du radius. Rev Chir Orthop Reparatrice Appar Mot 2001;87:124–9.
[8] Lin C, Sun JS, Hou SM. External fixation with or withouth supplementary intramedullary Kirschner wires in the treatment of distal radial fractures. Can J Surg 2004;47:431–7.
[9] Leung KS, Shen WY, Tsang HK, Chiu KH, Leung PC, Hung LK. An effective treatment of comminuted fractures of the distal radius. J Hand Surg Am 1990;15:11–7.
[10] McQueen MM. Redisplaced unstable fractures of the distal radius. A randomized prospective study of bridging versus non bridging external fixation. J Bone Joint Surg Br 1998;80:665–9.
[11] Carter PR, Frederick HA, Laseter GF. Open reduction and internal fixation of unstable distal radius fractures with a low-profile plate : a multicenter study of 73 patients. J Hand Surg Am 1998;23:300–7.
[12] Gesensway D, Putnam MD, Pl Mente, Lewis JL. Design and biomechanics of a plate for the distal radius. J Hand Surg Am 1995;20:1021–7.
[13] Rikli DA, Regazzoni P. Fractures of the distal end of the radius treated by internal fixation and early function. A preliminary report of 20 cases. J Bone Joint Surg Br 1996;78:588–92.
[14] Obert L, Vichard P, Garbuio P, Tropet Y. Ostéosynthèse des fractures du radius distal par plaque postérieure : avantages et inconvénients. Chir Main 2001;20:436–46.
[15] Bahm J, Faye N, Nonnenmacher J. Surgical treatment of fractures of the distal radius : a closed therapy concept. Initial results with the bowl osteosynthesis. Chirurg 1994;65:999–1003.
[16] Orbay JL, Fernandez DL. Volar fixed-angle plate fixation for unstable distal radius fractures in the elderly patient. J Hand Surg Am 2004;29:96–102.
[17] Schernberg F. Les substituts osseux en chirurgie de la main. In: Cahier d'enseignement de la Société Française de Chirurgie de la Main. Paris: Expansion Scientifique publications; 1997. p. 17–40.
[18] Roux JL. La prothèse de remplacement et resurfaçage du radius distal : un nouveau concept thérapeutique. Chir Main 2009;28:10–7.
[19] Lu-Yao GL, Keller RB, Littenberg B, Wennberg JE. Outcomes after displaced fractures of the femoral neck: a meta-analysis of one hundred and six published reports. J Bone Joint Surg Am 1994;76:15–25.
[20] Wretenberg P, Ekelund A. Acute hemiarthroplasty after proxiaml humerus fracture in old patients. A retrospective evaluation of 18 patients followed for 2-7 years. Acta Orthop Scand 1997;68:121–3.
[21] Appleton P, Moran M, Houshian S, Robinson CM. Distal femoral fractures treated by hinged total knee replacement in elderly patients. J Bone Joint Surg Br 2006;88:1065–70.
[22] Morrey BF. Fractures of the distal humerus: role of elbow replacement. Orthop Clin North Am 2000;31:145–54.
[23] Cobb TK, Beckenbaugh RD. Biaxial total-wrist arthroplasty. J Hand Surg Am 1996;21:1011–21.
[24] Levadoux M, Legré R. Total wrist arthroplasty with Destot prosthesis in patients with post-traumatic arthritis. J Hand Surg Am 2003;28:405–13.
[25] Roux JL. Wrist hemiarthroplasty for distal radius fractures: 10 years of experience. Hand 2016;11:45–6.
[26] Vergnenègre G, Hardy J, Mabit C, Charissoux JL, Marcheix PS. Hemiarthroplasty for complex distal radius fractures in elderly patients. J Wrist Surg 2015;4:169–73.
[27] Herzberg G, Burnier M, Marc A, Izem Y. Primary wrist hemiarthroplasty for irreparable distal radius fracture in the independent elderly. J Wrist Surg 2015;4:156–63.
[28] Ichihara S, Díaz JJH, Peterson B, Facca S, Bodin F, Liverneaux P. Distal radius isoelastic resurfacing prosthesis: a preliminary report. J Wrist Surg 2015;4:150–5.
[29] Tsang P, Walton D, Grewal R, MacDermid J. Validation of the QuickDASH and DASH in patients with distal radius fractures through agreement analysis. Arch Phys Med Rehabil 2017;98:1217–22.
[30] Herzberg G, Burnier M. Analyse radiologique des fractures fraîches de l'extrémité distale du radius et évaluation clinique des résultats. Hand Surg Rehabil 2016;35:15–23.
[31] Laulan J, Bismuth JP, Clément P, Garaud P. Classification analytique des fractures de l'extrémité distale du radius : la classification « M.E.U.». Chir Main 2007;26:293–9.
[32] Obert L, Lepage D, Saadnia R, Mille F, Rey PB, Loisel F. Fractures de l'extrémité distale du radius : quelle classification choisir? Hand Surg Rehabil 2016;35:24–7.
[33] Pechlaner S, Kathrein A, Gabl M, Lutz M, Angermann P, Zimmermann R, et al. Distal radius fractures and concomitant lesions. Experimental studies concerning the pathomechanism. Handchir Mikrochir Plast Chir 2002;34:150–7.
[34] Laulan J, Bismuth JP. Intracarpal ligamentous lesions associated with fractures of the distal radius : outcome at one year. A prospective study of 95 cases. Acta Orthop Belg 1999;65:418–23.
[35] Obert L, Uhring J, Rey PB, Rochet S, Lepage D, Leclerc G, et al. Aspects anatomiques et biomécaniques des fractures du radius distal de l'adulte : revue de la littérature. Chir Main 2012;31:287–97.
[36] Huard S, Leclerc G, Sergent P, Serre A, Gasse N, Lepage D, et al. Fractures du radius distal à déplacement dorsal : corrélation entre scores fonctionnels, qualité de réduction et type de fixation. Chir Main 2010;29:366–72.
[37] Souer JS, Ring D, Matschke S, Audige L, Marent-Huber M, Jupiter JB. Effect of an unrepaired fracture of the ulnar styloid base on outcome after plate-and-screw fixation of a distal radial fracture. J Bone Joint Surg Am 2009;91:830–8.
[38] Namba J, Fujiwara T, Murase T, Kyo T, Satoh I, Tsuda T. Intra-articular distal ulnar fractures associated with distal radial fractures in older adults: early experience in fixation of the radius and leaving the ulna unfixed. J Hand Surg Eur 2009;34:592–7.
[39] Wood DJ, Smith AJ, Collopy D, White B, Brankov B, Bulsara MK. Patellar resurfacing in total knee arthroplasty: a prospective, randomized trial. J Bone Joint Surg Am 2002;84:187–93.
[40] Fischer LP, Olivier H. Le cotyle face aux prothèses fémorales. Symposium SOFCOT. Rev Chir Orthop Reparatrice Appar Mot 1978;65:125–63.