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ORIGINAL ARTICLE

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Cement pinning of osteoporotic distal radius fractures with an injectable calcium phosphate bone substitute: report of 6 cases

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Abstract The treatment of osteoporotic distal radius fractures is frequently complicated by secondary displacements, mainly because of the posterior comminution. This work studies the advantages of injectable calcium phosphate cement, applied in addition to osteosynthesis with intrafocal pins. Our series comprises six osteoporotic patients with an average age of 77.5 years, showing a fracture of the distal radius osteosynthesized with pins. Cement has then been injected via the radial styloid. The result has been evaluated at an average interval of 14.7 months. The pain has been measured on an analogue visual scale and overall function by the DASH score. Mobility and gripping strength have been compared with the controlateral side. Radiographies have shown the presence of cement leakages, studied the resorption rate and measured secondary displacement. On the clinical level, the pain at the last examination was estimated at an average of 0.66 and total function at 30.28. Compared to the controlateral side, flexion-extension mobility was on average 95.3%, prono-supination 99%, and gripping strength 80.25%. There have been complaints of two resolutive reflex sympathetic dystrophy. Radiologically, the cement has distributed itself along the path of the trocar, in average quantities of 2 ml. Three anterior leaks of cement have been noticed, resorbed within a few months. The radio-ulnar index has lost on average 1.7 mm but the inclination of the radial glene has remained stable. At the last examination, resorption of the intra-osseous cement was partial three times and subtotal three times. Despite the paucity of the sample, it appears that adding calcium phosphate cement does not reduce secondary displacements. The asymptomatic extra-osseous leakages of cement disappeared on average in 6 months. The intra-osseous cement's resorption rate was slower. Despite the partial results, calcium phosphate cements retain a place in the treatment of distal radius fractures, provided that they remain injectable and address unstable fractures in porotic bone.

Keywords Bone substitute · Distal radius · Hydroxyapatite · Injectable cement · Calcium phosphate

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Cimentobrochage des fractures du radius distal ostéoporotique avec un substitut osseux phosphocalcique injectable: à propos d'une série préliminaire de 6 cas

Résumé Le traitement des fractures du radius distal ostéoporotique est fréquemment compliqué de déplacements secondaires quel que soit le type d'ostéosynthèse. La cause est la comminution liée à la fragilité corticale postérieure et le tassement trabéculaire. Ce travail étudie l'intérêt d'un ciment phosphocalcique injectable, en complément d'une ostéosynthèse par broches. Notre série comporte six patientes ostéoporotiques d'âge moyen 77,5 ans, présentant une fracture du radius distal ostéosynthésée par broches intrafocales. Un ciment phosphocalcique a ensuite été injecté par la styloïde radiale. Le résultat a été évalué au recul moyen de 11,5 mois. La douleur a été mesurée sur une échelle visuelle analogique et la fonction globale par le score de DASH. La mobilité et la force de serrage ont été comparées au côté controlatéral. Les radiographies ont constaté la présence de fuites de ciment, étudié sa vitesse de résorption, et mesuré le déplacement secondaire. Sur le plan clinique, la douleur au dernier recul était côté en

moyenne à 1,6 et la fonction globale à 34,3. Par rapport au côté controlatéral, la mobilité en flexion-extension était en moyenne de 95,3 %, en prono-supination de 99%, la force de serrage de 80,25 %. Deux algoneurodystrophies résolutives ont été déplorées. Radiologiquement, le ciment s'est réparti le long du trajet du trocart, avec une quantité moyenne de 200 mm3. Trois fuites antérieures de ciment ont été notées, résorbées en quelques mois. L'index radio-ulnaire a perdu en moyenne 1,7 mm, mais la pente de la glène radiale est restée stable. Au dernier recul, la résorption du ciment intraosseux était partielle 3 fois et subtotale 3 fois. Malgré la faiblesse de l'échantillon, il apparaît que l'adjonction d'un ciment phosphocalcique ne diminue pas les déplacements secondaires. La technique pourrait être améliorée en formant une cavité centromédullaire destinée à être comblée. Les fuites de ciment extra-osseuses, asymptomatiques, ont disparu en moyenne en 6 mois. La vitesse de résorption du ciment intraosseux était plus lente. Malgré des résultats partiels, les ciments phosphocalciques conservent une place dans le traitement des fractures du radius distal, à condition de rester injectables, et de s'adresser à des fractures instables en os porotique.

Motsclés Ciment injectable · Hydroxyapatite · Phospho-calcique · Radius distal · Substitut osseux

Introduction

In the enormous body of locomotive system traumatology, the incidence of osteoporotic wrist fractures is one of the highest, estimated, for example, at 240,000 cases per annum in the USA [4]. These so-called Pouteau–Colles fractures often reveal osteoporotic disease and represent in themselves a major investment for public health. The causal mechanism, isolated by Pouteau [17] in the eighteenth century usually consists of a simple reduction in height. The most frequent etiology is osteoporosis, in postmenopausal women (type 1) or elderly patients (type 2) [22]. It is characterized by bone fragility caused both by reduction in the mineral mass and deterioration in the bone tissue's micro-architecture. At wrist level, when fractured according to the mechanism described by Lewis in 1950 [13], osteoporosis causes a significant subsequent comminution, with a loss of bone substance after reduction, aggravated by the weak natural resistance of the distal radius' posterior cortical. It is this phenomenon that is responsible for the secondary displacements after surgical reduction, because subsequent comminution is a source of instability, whatever the treatment employed.

The development in treatment of wrist fractures with posterior displacement has experienced three subsequently traditional major steps in the postwar years. The orthopedic method consisted of immobilizing the fractures, after their reduction, with a plaster support with the elbow in flexion and the wrist in hyperflexion [7]. Despite this advance, the persistence of secondary displacements has led to proposing osteosynthesis by styloidian pinning [2]. The secondary displacements have certainly diminished but have not dropped below a threshold of 37%, according to Castaing himself. When Kapandji published his intrafocal pinning technique [8], the enthusiasm was such that styloidian pinning practically was abandoned. But secondary displacements continue to be frequent occurrences and many authors have recently proposed various techniques to try to reduce them. Some recommend external fixation [5] and others still anterior [14] or posterior [20] plates, with variable results. However, the rate of secondary displacements still remains around 30% even today [25].

In this context, we think, along with certain authors, that there is a place for bone substitutes in the treatment of these fractures. It was Charnley [3] who was the first to use only cement in wrist fractures. But this was acrylic cement. It is Kopylov [10] who published the first use just of calcium phosphate cements in these fractures. But the good immediate radiographic results still ended in reduction losses. That is why other authors have combined them with the use of external fixation [23], or plates [20] or pins [6] to make up for the posterior loss of osseous material. Our proposal is to combine Kapandji's technique here with Cementek LV (Teknimed) injectable calcium phosphate cement. This is completely synthetic, apatitic, ionic or hydraulic cement.

After it is mixed, the cement forms a hydrated homogeneous paste composed of brushite, which sets in twenty minutes and leads to a succession of non-exothermic dissolution and recrystallization processes, which end finally in the formation of stable hydroxyapatite, which acquires its optimum mechanical properties after 72 h [12]. This is the bone substitute whose mineral structure, with a calcium/phosphorus ratio of 1.63, is closest to natural bone [19]. The hydroxyapatite of which it is composed is chemically non-stoechiometric, which means that there are significant ionic exchanges between the surface of the crystals and the extracellular medium. It is microporous, with pores of less than a micron, which explains the slowness to biodegrade, which is measured in years, depending on the volume implanted [15]. It is not macroporous, which gives it a strength of the order of 20 MPa under compression, which is three times greater than physiological trabecular bone.

This work aims to try to improve Kapandji's technique by combining injectable calcium phosphate cement with intrafocal pinning.

Materials and methods

Patients

Our series consists of six right-handed females, aged on average 77.5 years with extremes of 70–89 and afflicted with evident clinical osteoporosis (Table 1). All showed

Table 1 Result of six cement pinnig for osteoporotic distal radius fractures

Patient	I	II	III	IV	V	VI
Age (year)	80	81	71	70	89	74
History	Vertebral fracture	Controlateral radius fracture	Hysterectomy before 40-year-old	Hysterectomy before 40-year-old	Vertebral fracture	Breast cancer Bisphosphonates
Fracture						
AO classification	C1.1	A3.2	A3.2	A3.2	A3.2	C2.1
Cooney classification	IVa	II	II	II	II	IVa
Technique						
Operative delay (day)	0	1	1	0	0	0
Amount of injected cement (ml)	2.5	1.8	2.4	1.5	2	1.8
Tourniquet duration (mn)	16	15	15	15	20	18
Leakage of cement	Anterior and external, resorbed in 5 months	0	Anterior, resorbed in 10 months	0	Anterior, resorbed in 3 months	0
Clinical outcome						
Follow-up (months)	19	14	10	18	15	12
Pain (0–10)	2	2	0	0	0	0
Function (DASH score)	52.5	25.8	4.2	66.7	20	12.5
Flexion-extension compared to controlateral side (%)	93	80	69	75	100	155
Prosupination compared to controlateral side (%)	100	100	100	94	100	100
Grip strengthcompared to controlateral side (%)	72	85	62.5	62	100	100
Complications	Impossible to remove the pins	Reflex sympathetic dystrophy	Reflex sympathetic dystrophy			
Radiological results compared to postoperative values						
Radio-ulnar (mm)	–	–	0	0	–	0
Inclination of the radial glene (°)	−5	+14	0	0	0	0
Cement resorption	Partial	Sub-total	Partial	Sub-total	Partial	Sub-total

prior signs but these were only recognized in one of them and had been treated with biphosphonates for 3 years. The other patients were unaware of their disease and none had been subject to densitometric diagnosis or specific or substitutive medical treatment.

In all cases, the wrist fracture was a consequence of a normal accidental fall. There were four extra-articular fractures and two articular fractures (Table 1). Only one of them was isolated, with no fracture to the ulna's styloid (case II).

Technique

The surgical procedure was conducted by the same specialist (first author) under local anesthetic by humeral block and pneumatic tourniquet inflated to 350 mm Hg at the base of the member. The tourniquet was inflated at the time of the incision and deflated when bandaging was complete, after the construction of a resin antebrachiopalmar splint. After orthopedic reduction by external maneuvering, three punctiform cutaneous incisions were made with a No. 11 surgical knife, one external and two posterior. Three 18-mm diameter pins were then introduced as in Kapandji's procedure [8] into the focus of the fracture percutaneously, by moving the extensor tendon system apart using a set of fine clawless Halstead pincers. Two pins were posterior and the third external. After installing the pins, a fourth punctiform cutaneous incision was made at the point of the radial styloid process, through which a 10-cm long, caliber 11 trocar was introduced. The trocar was then pushed along a line bisecting the angle delineated outside by the distal radius's lateral cortical and inside by the inclination of the radial glene.

The trocar's path terminated in contact with the radius's medial cortical without perforating it. A quantity of 20 mg of cement (Cémentek LV, Teknimed'', Vic in Bigorre, France) has been prepared by mixing by hand, producing a homogeneous malleable paste introduced into an injection syringe (BoC system, BOC-Grifols'', Parets del Vallès, Spain), to which the trocar has been adapted. The injection was then made under fluoroscope (7700, GE-OEC, Buc, France) to check the cementing operation's progress, which is stopped in the event of a leak of the product or when the operator considers filling to have been completed satisfactorily. Injection was continued by withdrawing the trocar to

the point of the radial styloid. The initial cutaneous path has occasionally been massaged by hand to remove any leakage through the injection puncture. The four initial percutaneous paths have been closed with a resorbable suture.

The postoperative procedures were traditional, with immobilization in a splint extending the wrist for 6 weeks, the date when the pins were removed as an outpatient procedure.

Measurement method

The clinical results have been evaluated at the date of the last examination based on pain, function, mobility, gripping strength and the presence of complications. Pain was measured on a visual analogue scale (VAS) of 0 (absence of pain) to 10 (extreme pain) and function by the DASH score from 0 (excellent result) to 100 (poor result). The total extent of mobility in the frontal plane and in prono-supination has been compared with that of the controlateral side and expressed in percentage form. The hand's total gripping strength measured by Jamar has been compared to that of the controlateral side and also expressed in percentage form. Lastly, the complications have been recorded.

The amount of cement injected has been obtained by reading from the graduated syringe after purging the trocar. Leakages have been observed in the fluoroscope and their development in the soft tissues has been checked radiologically over time. Successive X-ray photographs have also enabled evaluation of the calcium phosphate cement's resorption rate and measurement of the change in the radio-ulnar index from the front and the inclination of the radial glene in profile from immediate postoperative condition to the date of the last examination.

The paucity of the sample has not permitted any pertinent statistical analyses to be made.

Results

Four patients were operated on the day of the accident and the two others the day after. The period during which the tourniquet was applied was on average 16.5 min with extremes of 15 and 20 min (see Table 1). The average amount of cement injected was 2 ml, with extremes of 1.5 and 2.5. Three anterior leakages of cement were noted under the *pronator quadratus* without any notable complications and, particularly, no syndrome of compression of the median nerve in the carpal tunnel. In one of the three cases of leakage, a second location was noticed external to the styloidal injection point. It should be noted that all these extra-osseous leakages of cement were resorbed over a period of a few months (Fig. 1), whereas the cement located inside the bone had only partially been resorbed at the time of the last examination (Table 1).

At the clinical level, pain at the time of the last examination was calculated at an average of 0.66 on the visual analogue scale, with extremes of 0 and 2. Overall function, evaluated in DASH terms, was on average 30.28, with extremes of 4.2 and 66.7. The extent of mobility in terms of flexion-extension was on average 95.3% compared to the controlateral side, with extremes of 69 and 155. The extent of mobility in prono-supination terms was on average 99% compared to the controlateral side, with extremes of 94 and 100. The hand's overall gripping strength was on average 80.25% compared to the controlateral side, with extremes of 62 and 100. Lastly, two complications were noted, namely two resolutive reflex sympathetic dystrophy. In one case (patient 1), removal of the pins was impossible by the posterior path on the sixth week and were removed in a second stage via the anterior path.

On the radiological level, the cement distributed itself primarily along the injection trocar's path. From the front, the posteromedial area was never filled with cement and from the profile, the cement has remained centromedullar overall, distant from the distal radius's posterior cortical. The lower radio-ulnar index lost 1.7 mm on average compared to its immediate postoperative value, after cement pinning. The inclination of the radial glene remained stable, with a loss of $-.2°$ compared to its immediate postoperative value. Lastly, at the last examination, resorption of the calcium phosphate cement was considered as partial in three cases and sub-total in three cases.

Discussion

The use of bone substitutes is currently the subject of many studies. But the series published are still short or nonhomogeneous with summary description of the surgical technique [1, 9, 11]. The products used are very different, not only in terms of their physical/chemical properties but also their form of administration and the indications selected.

In this context, our prospective study contains too few a number of patients to obtain significant results. Nevertheless, in this osteoporotic field, it appears that adding an injectable calcium phosphate cement does not cause a decrease in secondary displacements compared to other osteosynthesis techniques. We think that this is due to the injection technique, which could be improved. In our series, injection was made without any intraosseous preparation, along the trocar's path, on the bisector of the radial styloid process from the front and at an equal distance from the anterior and posterior corticals in profile. This distribution is probably not biomechanically favorable to maintaining the reduction over time. We think it would be useful to fill the distal radial epiphase better, particularly in regard to the fracture zone in contact with the posterior cortical. To do this, it would be necessary to collapse the trabeculae to obtain a homogeneous centromedullar

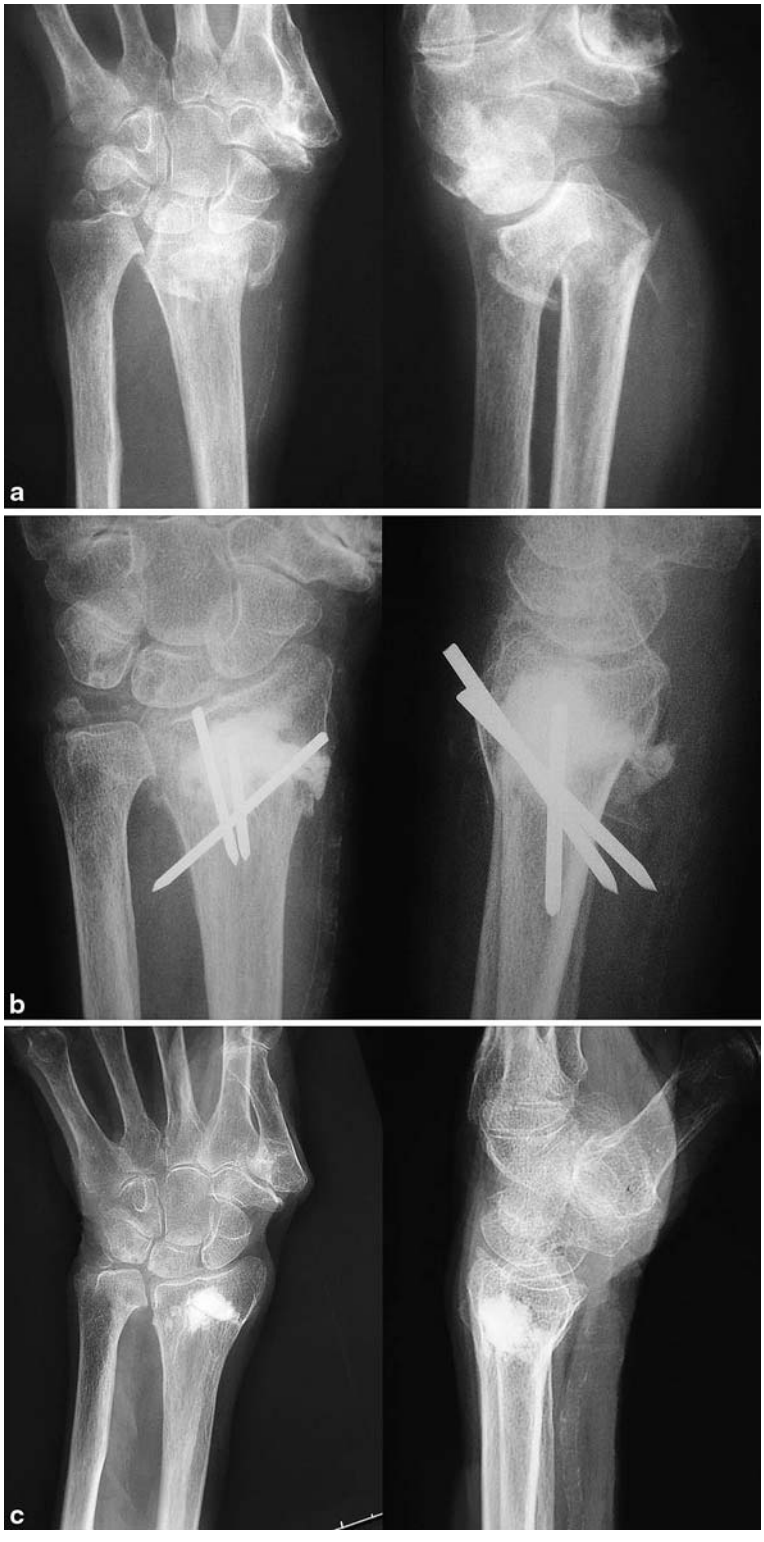

Fig. 1 Case No. III. X-ray photographs immediately before the operation (**a**), immediately after (**b**) and 15 months after (**c**) cement pinning of a distal radius fracture. Significant anterior leakages of cement can be noticed, which are progressively resorbed. At the same time, the intraosseous cement is subject to very slow resorption. At the final examination, the cement has undergone partial resorption

cavity from the sub-chondrial zone to the metaphyso–epiphysary zone. This cavity could be filled using the same injection technique but guiding the trocar in profile towards the posterior cortical. We have already shown during an experimental anatomical study that filling such a cavity with calcium phosphate cement increased the osseous resistance of the distal radius [16].

The question of the trocar's point of penetration—styloidian, diaphysary or according to the fracture line—has also been mentioned in this previous work. We think we have shown that the point of the radial styloid

process was the best choice because of its harmless nature and the trocar's ease of manual penetration without motor-driven aids [18]. The diaphyso-metaphysary proximal path has some inherent potential risks of tendon and nerve lesions and even of fractures of the radial diaphysis when drilling the trocar's penetration hole. Certain authors [6, 11, 21] have the trocar penetrate via the fracture line. We have already stressed the disadvantages of this fracture path [18], a fragile area par excellence where the radius's posterior cortical risks being mistreated even more by the trocar's to-and-fro movements and its turning around to obtain the best fill possible.

In our series, extraosseous leakages of cement, contrary to the experience of other authors, have not caused any clinical manifestations and, in particular, no carpal tunnel syndrome [21] or inflammatory phenomena [26]. It is possible that the chemical composition of the calcium phosphate cement used here, which is very close to that of bone, explains the absence of any inflammatory phenomena. Whatever the reason, we have noticed no intra-articular leakage of cement, contrary to the experience of other [24].

In our series, the leakages could lodge forward under the *pronator quadratus*, inside towards the ulna or at the level of the trocar's penetration point, the point of the radial styloid process. In the first two cases, the leak is propagated through the focus of the fracture. We think that despite the presence of known osteoporosis, the pressure of collapse of the trabeculae by injecting cement remains higher than that of leakages through the fracture line. This is an additional argument in favor of a maneuver to collapse the trabeculae, which would create a cavity which it would require virtually no pressure to fill, thereby limiting the risk of extra-osseous leakage of cement. Lastly, in the case of leakages at the trocar's penetration point, it has always been possible to reduce these leakages and even make them disappear by simple cutaneous massage of the initial path.

In our three cases of extra-osseous leakage, spontaneous disappearance of these leakages of cement has been noticed radiologically, after an average period of 6 months (ranging from 3 to 10). On the other hand, the rate of cement resorption was much slower in the intraosseous location. Here, only partial or sub-total disappearance of the cement was noted after the final examination at an average of 14.7 months. It therefore appears that the calcium phosphate cement's resorption rate varies according to its location. In the extraosseous area, the cement disappears in a few weeks, whereas in the intraosseous area it persists for at least a year.

The mechanisms responsible for this resorption are probably different. In the extra-osseous area, the disappearance of the cement could be connected to acido–basic phenomena, whereas in the intra-osseous area, its disappearance gives way to normally oriented trabeculae. In successive X-ray photographs, we have never observed any progressive migration of cement into the soft tissues, which could have indicated lymphatic or vascular elimination or along the aponeurotic spaces of the compartments of the forearm. There is no evidence of a margin around the osseous substitute. On the whole, we think that moderate leakages of cement are not a major obstacle to its use.

Only one specific complication has been observed with calcium phosphate cement in this series. This concerned a technical impossibility of removing the pins by the dorsal path because the pins were solidly anchored in the cement. The pins were finally removed secondarily by the anterior path. The two reflex sympathetic dystrophy in the series are nothing specific in this type of fracture.

We think that despite the imperfect results, bone substitutes retain a place in the treatment of distal radius fractures under certain conditions. Their method of administration must remain minimally invasive (therefore injectable) and their use must be restricted to instable fractures or fractures in porotic bone, whose weak mechanical resistance does not allow sufficient support for a traditional osteosynthesis. In the light of the results obtained, the injection technique must remain open to change. We think that preparation by collapsing the trabeculae should permit better filling during injection of cement and therefore improvement in fitting in terms of resistance to compression with a view to reducing the rate of secondary displacements. Among all the osseous substitutes currently available, non stoechiometric hydroxyapatite offers the advantage of microporosity, which confers a mechanical resistance superior to that of trabecular bone, and a slow resorption rate, which lends long-term solidity to the assembly until the bone finally consolidates.

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