Radial metaphyseal core decompression and stable fixation of proximal pole scaphoid nonunion without osteonecrosis

Ignacio Rellán, Gerardo L. Gallucci, Jorge G. Boretto, Agustín Donndorff, Ezequiel E. Zaidenberg, Pablo De Carli

Hand and Upper Limb Surgery Department, Instituto de Ortopedia y Traumatología "Dr. Prof. Carlos E. Ottolenghi", Hospital Italiano de Buenos Aires (Buenos Aires, Argentina)

ABSTRACT

Objective: To report the consolidation rate and the outcomes of a series of 22 patients with proximal pole scaphoid nonunion treated with a radial metaphyseal core decompression and an anterograde self-compressing screw. **Materials and Methods:** We present a prospective series of patients with proximal scaphoid pole nonunion and confirmation of intraoperative bleeding in both fragments. Patients presenting with displacement, degenerative changes, proximal pole fragmentation, cavitation at the fracture site, reduced bone length, and necrosis, as well as those with carpal instability, were excluded. X-rays and CT scans were performed to assess consolidation; range of motion and grip strength were recorded, and patients completed a visual analogue scale for pain at rest, pain during activity, and subjective functional status, as well as a DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire. **Results:** Eighteen patients were included. Union was observed in 17 patients. The average follow-up time was 22 months, and the average final range of motion was as follows: 87% for flexion, 84% for extension, 78% for radial deviation, 84% for ulnar deviation, and 85% for grip strength. The average score on the visual analogue scale was 0 for pain at rest, 2 for pain during activity, and 9 for function, while the average DASH score was 8. **Conclusions:** Using this simple and reliable technique, we obtained a 95% union rate and very good functional results. Radial metaphyseal core decompression with an anterograde screw is a valid and effective alternative for treatment of proximal pole scaphoid nonunion in carefully selected patients.

Key words: Scaphoid; proximal pole; nonunion.

Level of evidence: IV

Bloqueo óseo metafisario de radio y fijación estable en seudoartrosis de polo proximal de escafoides sin necrosis

RESUMEN

Objetivo: Reportar la tasa de consolidación y los resultados de una serie de 22 pacientes con seudoartrosis del polo proximal del escafoides tratados con un bloqueo óseo metafisario asociado a un tornillo autocompresivo anterógrado. **Materiales y Métodos:** Serie prospectiva de pacientes con seudoartrosis del polo proximal del escafoides en quienes se constató un sangrado intraoperatorio en ambos fragmentos. Se excluyó a los pacientes con desplazamiento, cambios degenerativos, fragmentación del polo proximal, cavitación del foco, pérdida de altura, necrosis y aquellos con inestabilidad carpiana. Se tomaron radiografías e imágenes por tomografía computarizada para evaluar su consolidación; se registraron la movilidad y la fuerza de puño, y los pacientes completaron una escala analógica visual para dolor en reposo, dolor en actividad, estado subjetivo funcional y el cuestionario DASH. **Resultados:** La serie incluyó 18 pacientes. Diecisiete presentaron consolidación. El seguimiento promedio fue de 22 meses y la movilidad final promedio fue: flexión 87%, extensión 84%, desviación radial 78%, desviación cubital 84% y fuerza de puño 85%. El puntaje promedio de la escala analógica visual fue 0 para dolor en reposo; 2, para dolor en actividad y 9 para función, en tanto que el puntaje DASH promedio fue de 8. **Conclusiones:** Con esta técnica confiable y sencilla, obtuvimos una tasa de consolidación del 95% y un muy buen resultado funcional. El bloqueo óseo metafisario asociado a un tornillo anterógrado constituye una alternativa válida y eficaz para tratar la seudoartrosis del polo proximal del escafoides, vital en pacientes cuidadosamente seleccionados.

Palabras clave: Escafoides; polo proximal; seudoartrosis.

Nivel de Evidencia: IV

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INTRODUCTION

Proximal pole scaphoid nonunion (PPSN) is a complex condition due to the anatomy of the proximal pole of the scaphoid. First, its small size may hinder fixation, thus ruling out proper stabilization. Being immersed in synovial fluid, the possibilities of consolidation are reduced. Second, the poor blood flow supplied by retrograde circulation could limit the possibility of scaphoid consolidation at this site[1]. Third, the carpal instability that results from this type of nonunion would also hinder the possibilities of consolidation and may evolve to post-traumatic osteoarthritis[1,2].

Initially, PPSN was treated by simple resection of the proximal pole, or resection and placement of various types of spacers or implants, but all these procedures were unsuccessful.

Subsequently, the treatment of this condition focused on reconstructing the broken scaphoid through a biological stimulus, both osteogenic and vascular, and providing mechanical stability to the scaphoid fragments. To this end, the use of bone grafts (vascularized or not), fixed with pins or screws, was adopted.

The most common approaches for the internal fixation of the scaphoid with self-compressive screws are the palmar and the dorsal.

The latter facilitates the positioning of the screw at the center of the proximal pole, thus increasing compression between both fragments, without compromising its vascular supply, provided that the capillaries that enter through the distal tubercle and into the dorsal neck of the scaphoid are preserved[3].

Although, nowadays, the advantage of using vascularized bone grafts in patients with PPSN and osteonecrosis is clear, this indication would be a little more controversial in patients with a vital proximal pole. This type of surgery has the disadvantage of requiring specific training and adequate equipment, which are not always available.

In 2001, Illarramendi and colleagues[4] reported metaphyseal core decompression to successfully treat Kienböck's disease. Although it has not yet been possible to demonstrate the way in which this simple surgical approach works, its benefits for the treatment of this condition are widely-known. Probably, this procedure would produce a cytokine-mediated regional vascular change that would improve vascularization in the wrist area, leading, by some unknown mechanism, to a "vascular excess" in the area[4].

In 2005, a treatment protocol for PPSN without carpal collapse or avascular necrosis was designed. It was approved by the Ethics Committee of our institution and consists of a combination of two approaches: anterograde fixation with a self-compressive headless screw for mechanical stabilization and metaphyseal core decompression for vascular stimulation and consolidation.

The objective of this paper is to report the consolidation rate observed while evaluating, both objectively and subjectively, a series of patients diagnosed with PPSN and treated with anterograde fixation using a cannulated self-compressive screw together with metaphyseal core decompression.

MATERIALS AND METHODS

We designed a protocol to treat patients diagnosed with PPSN and surgically treated in our Department. Nonunion was defined as any proximal pole scaphoid fracture that, after 12 or more weeks, did not show any signs of apparent consolidation or nonunion on X-rays or CT scans, regardless of the time elapsed since the fracture.

The Herbert classification[5] was used to define the type of nonunion, and the Schernberg classification[6] was used to evaluate the location of the nonunion, types I and II being considered as proximal pole nonunions. In addition, final postoperative mobility was measured with a goniometer and expressed as a percentage with respect to the contralateral wrist and the grip strength recorded by a Jamar dynamometer (Patterson Medical Co, Bolingbrook, Illinois [USA]), also expressed as a percentage, with respect to the contralateral hand.

All patients with PPSN and no radiographic or tomographic signs of osteonecrosis were included, as well as those in whom intraoperative bleeding of both fragments was confirmed by a deflated tourniquet cuff. The cases studied by preoperative MRIs showed signal changes consistent with edema or bone ischemia, but no osteonecrosis was observed.

We excluded patients who presented degenerative changes, fragmentation or comminution of the proximal pole, cavitation of the fracture site that included the entire lateral surface of the scaphoid, shortening, carpal instability secondary to nonunion (dorsal/palmar instability of the intercalated segment), and those with a follow-up <6 months.

Surgical approach

The patient was placed in the supine position. Under regional anesthesia, the scaphoid was dorsally approached through a 2 cm-long incision between the second and the fourth extensor tendon compartment and 1 cm distal to Lister's tubercle. A capsulotomy was performed on the ulnar side of the second extensor tendon compartment, taking special care to preserve the dorsal scapholunate ligament. The nonunion site was identified, and fibrosis was resected. The proximal pole showed adequate bleeding into the skin when applying curettage after removing the tourniquet cuff. The wrist was then placed in maximum flexion and ulnar deviation and, under fluoroscopy, a cannulated screw was placed in the center of the proximal pole, sinking its head into the subchondral bone and confirming the absence of protrusion at the radioscaphoid joint. For the first cases, we used 2.3 mm-cannulated cancellous screws (Synthes®), while for the most recent patients we used 2.0 mm-headless double-thread cannulated screws (Osteomed®).

After profuse washes and an adequate hemostasis, the capsule was closed. In the first cases, metaphyseal core decompression was performed between the second and fourth dorsal compartment using the same incision that was used to treat the scaphoid but extending it 2 cm to the proximal pole. In the most recent cases, the incision was the same size, although located on the lateral surface of the distal radius, a centimetre proximal to the radial styloid process, preserving and dividing the sensory branches of the radial nerve (Figure 1). Once in the cortical bone, a 1 cm-metaphyseal bone window was created on the side, through which the cancellous bone accessed by the osteotomy was impacted towards the other three areas of cortical bone (dorsal, ventral and ulnar), taking special caution not to damage them[4, 7]. Then we performed periosteal stripping of the cortical bone around the osteotomy, and the soft tissue was closed along its planes. After the procedure, the forearm and the palm of the patient were secured with a plaster splint.

All patients received follow-up X-rays at 6 weeks, without the plaster splint. In case of potential radiographic consolidation, a CT scan was performed to confirm the diagnosis. Patients without signs of radiographic consolidation had their plaster splint remade, and the scans were repeated six weeks later. At this time point, X-rays and CT scans without contrast were taken to evaluate nonunion consolidation.

The criteria to define consolidation were the disappearance of the osteolytic nonunion site and the absence of space between the fragments, with trabecular bone continuity between them in at least two CT scans performed in the three planes[8]. An Argentina Spanish validated version of the DASH questionnaire was used for subjective evaluation[9]. A visual analog scale from 0 to 10 (0 being a complete absence of pain and 10, the worst pain imaginable) was used to describe pain at rest, pain during activity, and functional status (0 being complete lack of function and 10, optimal function). During the physical examination, presence of discomfort caused by osteosynthesis and other complications was evaluated. A complication was defined as any deviation from the expected postoperative progress that caused pain or functional limitation, or that required additional treatment (surgical or medical).

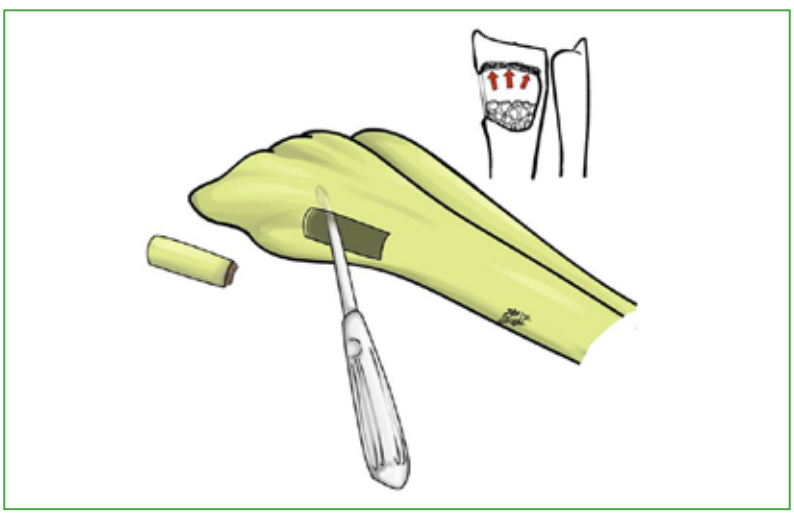

Figure 1. Illustration of the distal radius showing the metaphyseal core decompression approach: through a cortical bone window of 2 cm long and 1 cm wide, the cancellous bone is impacted with a curette, taking special care not to damage the cortical bone. (Reproduced with permission from the authors[7]).

RESULTS

Between 2005 and 2017, 23 patients diagnosed with PPSN were surgically treated at our institution. Three patients were excluded because they were lost to follow-up and could not be contacted, another patient was excluded due to preoperative stage 1 wrist osteoarthritis secondary to SNAC (Scaphoid Non-union Advanced Collapse), and another case was excluded from the series due to a proximal pole refracture. This was included as a complication of the method in question, but it was excluded from the analysis of this series, since the results are a consequence of the salvage therapy and not of the proposed approach. Three of the 18 patients included in the series were Herbert type D1, and 15 were Herbert type D2[8]. According to Schernberg and colleagues' classification[9], all patients were type II (Table 1).

Table 1. Demographic data

Patient	Side	Age (years)	Gender	Nonunion classification according to Herbert	Nonunion classification according to Schernberg	Time (months)
1	R	30	M	D2	II	18
2	L	27	M	D2	II	12
3	L	24	M	D2	II	4
4	R	33	M	D2	II	132
5	L	34	M	D2	II	13
6	L	21	F	D2	II	6
7	R	30	M	D2	II	6
8	D	29	M	D1	II	NA
9	L	26	M	D1	II	36
10	R	20	M	D2	II	NA
11	R	35	M	D2	II	36
12	R	27	M	D2	II	NA
13	L	21	M	D1	II	3
14	L	31	M	D2	II	NA
15	L	36	M	D2	II	NA
16	R	22	M	D2	II	12
17	L	30	M	D2	II	4
18	L	23	M	D1	II	8
19	L	22	M	D2	II	10
20	L	22	M	D2	II	3
21	L	26	M	D2	II	8
22	L	29	M	D2	II	521
Average		**27**				**81**

R: right, L: left, M: male, F: female. NA: not available.

Seventeen patients presented consolidation confirmed by both X-rays and CT scans (Figures 2 and 3). The average follow-up time was 22 months, and the average mobility range compared with the contralateral wrist was as follows: 87% for flexion, 84% for extension, 78% for radial deviation, 84% for ulnar deviation and 85% for grip strength (Table 2).

Figure 2. **A** and **B.** X-rays and CT scans that reveal a 4 month-proximal pole nonunion. **C** and **D.** X-rays and CT scan, one year and four months after surgery, respectively. Consolidation can be observed.

Figure 3. Male with a 10 month-trauma history. **A** and **B.** Preoperative X-rays and CT scans revealing a proximal pole nonunion. **C** and **D.** X-rays and CT scans 6 months after surgery. Consolidation can be observed.

Table 2. Results

Patient	Follow-up (months)	VAS (Rest)	VAS (Activity)	VAS (Function)	DASH	Flexion (%)	Extension (%)	Radial deviation (%)	Ulnar deviation (%)	Grip strength (%)
1	15	0	2	9	4	84	82	83	80	83
2	38	0	0	10	2	80	79	90	86	85
3	6	2	5	8	3	75	85	66	75	78
4	54	0	0	10	0	90	78	75	79	80
5	20	2	5	8	17	85	80	85	80	90
6	19	1	1	9	1	90	85	70	82	87
7	12	0	8	7	19	100	89	76	80	133
8	32	0	0	9	0	93	79	78	100	114
9	36	0	3	9.5	5	69	88	77	89	64
10	12	0	3	9	9	114	100	100	90	100
11	32	0	1	6	18	67	44	44	57	76
12	8	0	1	10	0	97	103	100	100	95
13	10	5	3	9	30	97	75	87	92	54
14	5	0	0	9	2	98	100	57	98	63
15	12	0	2	9.5	4.5	88	77	90	93	86
16	14	0	2	8	11	94	100	80	86	78
17	4	0	0	8	2	67	125	100	80	92
18	32	1	5	9	25	75	76	40	67	66
19	14	0	1	8	7	86	85	92	86	80
20	10	1	2	9	5	81	80	83	81	85
21	23	1	0	7	6	80	78	75	73	75
22	15	0	0	7	7	84	90	85	90	80
Average	**19**	**1**	**2**	**9**	**8**	**86**	**85**	**79**	**84**	**84**

VAS: visual analog scale

According to the visual analog scale, the average score for pain at rest was 0; 2 for pain during activity, and 9 for functional status; the average DASH score was 8. One patient (case 13) progressed unfavourably, without signs of consolidation, although without pain. Arguing personal reasons, the patient postponed salvage surgery for the next few months.

During follow-up, there was only one complication, classified as type I (antiemetics, diuretics or pain killers were required). Said patient (case 8) felt discomfort at the site of entry of the screw, together with neuropathic pain on the scar on the lateral face of the distal radius, through which metaphyseal core decompression had been performed. This was completely and spontaneously resolved. Therefore, there were three complications in this series: a patient with a proximal pole refracture, a nonunion, and a case of neuropathy of the sensory branch of the radial nerve.

DISCUSSION

To date, few studies address this problem in a specific way and, for the most part, they focus on necrotic PPSN. The multiple ways of defining the proximal pole of the scaphoid, the multiple treatments proposed, and the various diagnostic criteria for consolidation make it difficult to arrive at conclusions combining the available evidence.

In a meta-analysis of scaphoid nonunion, Merrel and colleagues[10] showed a 67% global success rate in cases of PPSN[10]. However, the high failure rate includes patients treated with different methods and approaches, many of which do not include a "biological" contribution.

Several surgical approaches have been reported using vascularized bone grafts, all with a high success rate[11-14]. However, this type of surgery not only increases the morbidity of the procedure, but also entails greater technical difficulty, greater surgical training, a higher economic cost and a longer operating time, all unnecessary factors for a patient with a vital proximal pole, no previous surgical failures, and an adequate pole size to allow screw fixation.

Based on the metaphyseal core decompression concept[4], which mechanism has yet to be proved but with an obvious clinical effectiveness, we incorporated this surgical approach to the treatment of PPSN. It is believed that metaphyseal core decompression increases vascularity of the area and promotes some degree of regional bone repair response by the body, likely mediated by the same substances or cytokines that participate in the cascade of events that follow a fracture. Therefore, there would be a benefit for patients with conditions compromising vascularization, such as PPSN or Kienböck's disease[7]. This theory is supported by the study carried out by Sherman and colleagues[15], in which they proved that metaphyseal core decompression does not affect strength at the wrist joint. Kam and colleagues[16], in their study of radial osteotomies for the treatment of Kienböck's disease, concluded that the resulting mechanical support would not be the physiological basis for their work, but rather that a fibrovascular stimulus secondary to said approach would determine the success of osteotomies in the treatment of said condition.

Matsuki and colleagues[17] reported a retrospective series of 11 consecutive cases treated with a non-vascularized bone graft and a Herbert screw, reaching a 100% consolidation rate. Using the same treatment, DeeMaagd[18] and Inoue[19] published two series with a consolidation rate of 89% (8 of 9 patients) and 81% (13 of 16 patients), respectively. In two series of patients with vital proximal pole treated with an anterograde screw without a bone graft, Krimmer[20] and Herbert[21] reported a consolidation rate of 74% (17 of 23 patients) and 75% (12 of 16 patients), respectively.

In our series of patients with PPSN treated with an anterograde screw and metaphyseal core decompression, we reached consolidation in 17 of 18 patients (94%), a rate that far exceeds those mentioned above and that is consistent with the 100% consolidation rate reported by Matsuki[17], although with a bigger patient population. In all cases, an anterograde screw fixation was performed through a dorsal approach. This technical detail is key to facilitate the central placement of the osteosynthesis in the small fragment of the proximal pole of the scaphoid, thus generating greater compression at the fracture site[22, 23]. Although this fixation approach is performed through a joint, cartilage damage produced by the screw entry site is small and, in the experience of all surgeons treating this case, it has never produced symptoms in cases of nonunions or fractures. During the treatment of this series of patients, we changed to a lateral approach to perform metaphyseal core decompression, since lateral cortical bone is tougher than the dorsal one and, this way, the area would be less temporarily weakened. In any case, metaphyseal core decompression can be carried out interchangeably in any of the two ways.

We believe this approach is reliable and simple. It does not require a microscope, training in microsurgery. or expensive instruments. It should be noted that our results were achieved in patients with PPSN, but with a vital proximal pole and without carpal collapse secondary to the scaphoid injury. We do not know how patients with a necrotic proximal pole or carpal instability would progress using this approach, since they were not the target of this study.

As strengths of this research, we would like to note its considerable number of patients given the low incidence of this condition, the objective and subjective evaluation of the results, and the confirmation of consolidation in all cases by CT scans.

The weakness is that we have not studied the long-term impact of the entire nonunion process and its consolidation on a potential degenerative wrist condition. In the near future and with a longer follow-up, we hope to be able to answer these questions that may arise and that have not been answered on this paper.

Conflict of interest: Authors claim they do not have any conflict of interest.

I. Rellán ORCID iD: http://orcid.org/0000-0002-6846-0682
G. L. Gallucci ORCID iD: http://orcid.org/0000-0002-0612-320X
J. G. Boretto ORCID iD: http://orcid.org/0000-0001-7701-3852
A. Donndorff ORCID iD: http://orcid.org/0000-0002-6384-4820
E. E. Zaidenberg ORCID iD: http://orcid.org/0000-0002-1535-0586
P. De Carli ORCID iD: http://orcid.org/0000-0002-9474-8129

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