Long-term outcome of nonvascularized grafts for carpal scaphoid nonunion
58 cases with 8.8-years of follow-up

Résultats à long terme des greffes cortico-spongieuses non vascularisées pour pseudarthrose du scaphoïde carpien : cinquante-huit cas revus au recul moyen de 8,8 ans

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RÉSUMÉ

Le but de cette étude rétrospective était d'analyser les résultats obtenus dans 58 pseudarthroses du scaphoïde carpien ayant bénéficié d'une greffe cortico-spongieuse non vascularisée, afin de préciser les facteurs influençant les résultats et d'en déterminer les indications idéales et les limites.

Entre 1984 et 1999, 103 patients ont bénéficié d'une greffe cortico-spongieuse non vascularisée, seulement 57 (58 poignets) ont été revus (4 décédés, 30 ayant refusé de se déplacer en raison de l'éloignement géographique et 12 perdus de vue). Le recul moyen était de 106 mois (19-212). L'âge moyen était de 36 ans (20-62). Pour 45 patients, la fracture n'avait pas été initialement diagnostiquée et le délai moyen du diagnostic était de 35 mois (6-252). Dans la classification de Schernberg, la fracture était située : 11 fois en zone II, 40 fois en zone III et 7 fois en zone IV. Selon la classification d'Alnot, les stades de pseudarthrose se répartissaient en : stade I (13), stade IIA (20), stade IIB (22), stade IIIA (2) et stade IIIB (1). L'immobilisation après l'intervention a été en moyenne de 2,7 mois.

La consolidation a été obtenue dans 47 cas, en moyenne, au bout de 3 mois. Trente-six patients étaient très satisfaits, 18 satisfaits et 4 non satisfaits. Vingt-sept patients ont présenté des douleurs importantes sur la prise de greffe, mais celles-ci ont disparu en quelques mois et tous les patients ne gardaient au recul aucune séquelle. Par rapport au poignet sain, les amplitudes de mobilité étaient réduites pour la flexion (en moyenne de 8,7°), l'extension (en moyenne de 12,8°) et l'inclinaison radiale (en moyenne de 10,5°). Les autres secteurs de mobilité du poignet étaient respectés (en particulier la supination et la pronation). L'indice de hauteur du carpe était en moyenne de 0,54 (0,47-0,57), et 9 poignets avaient une hauteur diminuée. L'angle radio-lunaire était en moyenne de 4,8° (-17°, +27°). Vingt poignets avaient une déformation en DISI. 36 patients ne présentaient pas ou peu d’arthrose. Onze pseudarthroses n’ont pu être consolidées ; 7 d’entre elles présentaient au départ une nécrose du pôle proximal. Tous les patients ont été améliorés pour la douleur. La survenue de l’arthrose était favorisée par la persistance d’une déformation en DISI.

Si cette technique autorise 81 % de consolidation, elle est dépassée pour les stades arthrosiques évolués. La correction d’une déformation intra-carpienne en DISI apparaît indispensable pour prévenir la survenue de l’arthrose. Cette technique ne doit pas être proposée en cas de nécrose du pôle proximal, et il faut sans doute lui préférer un greffon vascularisé.

Mots clés : Scaphoïde, pseudarthrose, greffon, cortico-spongieux.

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INTRODUCTION

Fracture of the scaphoid is the most frequent fracture of the carpal bones [Leslie and Dickson (1)], with 5%-10% evolving toward nonunion [Alnot (2)]. Nonunion evolves inevitably toward osteoarthritic degeneration over the more or less long term when surgical treatment is not undertaken. Classically, nonunion treatment uses cancellous or corticocancellous graft, most often harvested from the iliac crest. With recent developments in microsurgery techniques, vascularized grafts have been proposed [Doi et al. (3), Gabl et al. (4), Guimberteau and Panconi (5), Mathoulin and Haerle (6)]. As a result, the classical technique of nonvascularized graft has been questioned. The purpose of our retrospective radiological and clinical study was to determine: 1) the limits of this carpal scaphoid nonunion graft method, 2) the factors influencing results, and 3) the ideal indication.

PATIENTS AND METHODS

Patients

Between 1984 and 1999, 103 patients presenting with scaphoid nonunion were treated with nonvascularized graft. During the study period, no other treatment was given for scaphoid nonunion. Of the 103 patients, only 57 were seen at follow-up (58 wrists because of one bilateral lesion), four had died, 30 refused to attend follow-up (because they lived too far away), and 12 were lost to follow-up. Subjects comprised 50 men and 7 women. There were 32 unilateral right-sided lesions, 24 left-sided lesions, and one bilateral lesion. Thirty-one patients had lesions on their dominant side, 25 on the nondominant side, and one patient on both sides. Mean follow-up was 108 months (range, 24-212). Patients’ mean age at the time of treatment was 26.7 years (range, 14-50). Mean age at follow-up was 35.5 years (range, 20-62). In 45 patients (77.6%), the fracture had not been diagnosed initially; 13 fractures had been diagnosed initially. Forty-three of the fractures had not had initial treatment, 11 had had a short arm cast for 3 weeks, and four had been treated by surgery (three with screw fixation and one with wire fixation). The time elapsed between the fracture and surgical treatment was a mean of 35 months (range, 6-252).

According to the Schernberg classification (7) (fig. 1), the fracture was located 11 times in zone II, 40 times in zone III, and seven times in zone IV. Using the Alnot classification (2), nonunion was grade I (n = 13), grade IIa (n = 20), grade IIb (n = 22), grade IIIa (n = 2), and grade IIIb (n = 1) (table 1).

Surgical method

The approach was anterior 54 times and posterior four times for proximal fractures (Schernberg zone II). The graft was harvested 50 times on the anterior iliac crest and eight
times on the distal radial epiphysis, a corticocancellous
graft 50 times, and cancellous eight times. In 46 cases,
freshening was carried out with a curette and in 12 cases
using a reamer. In 52 cases, an inlay was performed and in
six cases an intercalary graft. In 25 cases, there was osteo-
synthesis; 33 cases included 19 with wire fixation, nine
with screw fixation, and five with staple fixation. Immobili-
ization lasted a mean of 2.7 months (mean, 1.5-4 months).

**Evaluation method**

In addition to patients’ level of satisfaction, wrist pain
was evaluated in four grades (severe, moderate, low,
absent) as was pain at the graft harvesting site. We com-
pared affected wrist and unaffected wrist amplitude and
mobility. Thumb mobility was assessed according to
Kapandji’s criteria (8) of apposition and counter-apposi-
tion of the thumb. Grasp was measured using the Jamar
dynamometer, with the wrist in the functioning position,
elevator against the body, flexed at 90°. Three measurements
were taken on each side and we retained the mean value.
Thumb-index pinching strength was also measured on both
sides, with three measurements taken and the mean value
retained.

Carpal height was assessed using the MacMurtry index
[Sintzoff and Fumiere (9)]. The radiolunate angle was
measured on lateral wrist x-ray with a small board (fig. 2).
A value of 10° or higher was considered dorsal intercalated
segmental instability (DISI). A value of -25° or less was
considered a ventral intercalated segmental instability
(VISI).

Necrosis of the proximal pole was only sought on simple
x-rays and on the following signs: dense aspect, bony
resorption, and multiple punched out lesions. We were not
able to look for necrosis on the initial x-rays because many
of them had not been kept by the hospital or the patient
(only 60% of the preoperative x-rays were studied).

Function was evaluated by the Shah and Jones score (10)
(table II), which we found to be the best adapted to this
pathology, with both objective and subjective evaluation.
A score of 90 or more was considered excellent, between
80 and 89 good, between 70 and 79 average, and under 70
was considered poor. Following the same divisions as the
Shah score, we introduced a personal evaluation (table III),
which takes into account mobility in radioulnar inclination;
the subjective evaluation counted for one-fifth of the score
rather than half as in the original scoring system.

**Statistical analysis**

Statistical analysis was performed using Statview™
software. Analyses of variance were used to compare
means, the chi square test was used to compare categorical
variables. Regression analyses tested the relations

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**TABLE I.** *Nonunion stage in relation to severity of radial-carpal and intracarpal arthrosis according to Alnot (2).*

<table>
<thead>
<tr>
<th>Stage</th>
<th>X-ray aspect of nonunion</th>
<th>Intracarpal instability</th>
<th>Osteoarthrosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
<td>Linear nonunion with no modification of scaphoid shape</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Stage II</td>
<td>Stable nonunion, geodes, bony resorption</td>
<td>No</td>
<td>± Tapered radial styloid</td>
</tr>
<tr>
<td>IIA</td>
<td>Nonunion ± mobile, geodes, bony resorption, modification of scaphoid shape (misalignment)</td>
<td>Intracarpal adaptation and/or ligament misalignment with DISI</td>
<td>± Tapered radial styloid</td>
</tr>
<tr>
<td>IIB</td>
<td>Displaced nonunion, mobile</td>
<td>Reducible or fixed misalignment</td>
<td>Isolated radioscaphoid</td>
</tr>
<tr>
<td>Stage III</td>
<td>Displaced nonunion, mobile</td>
<td>Reducible or fixed misalignment</td>
<td>Radioscaphoid and intracarpal</td>
</tr>
<tr>
<td>IIIA</td>
<td>Necrosis of the scaphoid proximal pole</td>
<td>Misalignment</td>
<td>No</td>
</tr>
<tr>
<td>IIIB</td>
<td>Necrosis of the scaphoid proximal pole</td>
<td>Misalignment</td>
<td>Radioscaphoid and intracarpal</td>
</tr>
</tbody>
</table>
between numerical variables. Statistical significance was set at 5%.

RESULTS

Complications

No infections were observed in the 58 wrists, nor at the 50 iliac crest harvesting sites. Of the 50 patients who were treated with an iliac graft, 27 (54%) presented immediate severe postoperative pain. However, at follow-up, none presented pain at the harvest site. There were 11 nonunions that did not heal, with 81% that did heal. Of the 11 patients who did not heal, seven presented proximal pole necrosis (radiographic), three presented DISI at the last follow-up, and one presented no factor that could explain the absence of healing. Of the 11 persistent nonunions, four experienced no pain, six a low level of pain, and one moderate pain. Six of the 11 patients with persistent nonunion were very satisfied, four were satisfied, and only one was not satisfied. Of the seven cases of proximal pole necrosis of the scaphoid, two were nonunions in Schernberg zone II; the five others were located in zone III.

Consolidation and clinical result

For 47 fractures, healing was achieved in a mean of 3 months (range, 1.5-6 months). No pain or only moderate pain was experienced in 98% of the wrists; the progression of pain is detailed in table IV. At follow-up, mean overall mobility (table V) was normal only for pronosupination and ulnar inclination. Thumb apposition was a mean of 9.4 (range, 7-10) versus 9.5 (range, 7-10) on the healthy side.

<table>
<thead>
<tr>
<th>Table II. – Shah and Jones Score (10).</th>
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</thead>
<tbody>
<tr>
<td>Shah score</td>
</tr>
<tr>
<td>Union</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td>Fibrous union</td>
</tr>
<tr>
<td>Partial bony union</td>
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<tr>
<td>Complete bony union</td>
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<tr>
<td>Osteoarthritis</td>
</tr>
<tr>
<td>Mobility (entire carpal scaphoid)</td>
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<tr>
<td>Advanced</td>
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<tr>
<td>Moderate</td>
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<tr>
<td>Beginning</td>
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<tr>
<td>None</td>
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<tr>
<td>Mobility (flexion-extension arc compared to opposite side)</td>
</tr>
<tr>
<td>25–50%</td>
</tr>
<tr>
<td>51–75%</td>
</tr>
<tr>
<td>76–100%</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Strength (compared to opposite side)</td>
</tr>
<tr>
<td>26–50%</td>
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<tr>
<td>51–75%</td>
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<tr>
<td>76–100%</td>
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<tr>
<td>Normal</td>
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<td></td>
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<tr>
<td>Total</td>
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</tbody>
</table>
Counter-apposition was always 4 on both sides. Grip strength on the nonunion side was a mean of 37 kgf (range, 14-70; SD, 10.3) versus 41.5 kgf (range, 12-67; SD, 10.9) on the healthy side, i.e., 89% of the healthy side’s grip strength. Pinching strength on the nonunion side was a mean of 18.6 kgf (range, 6-28; SD, 4.1) versus 19.5 kgf (range, 6-30; SD, 4.5) on the healthy side. Pinching strength was 89% of the strength on the healthy side.

### Overall functional score

The objective Shah score was a mean of 79.9 and the mean subjective values was 92.7. The mean total Shah score was 172.6 (maximum total, 200 points). From an objective point of view: 15 wrists presented an excellent result, 22 a good result, 12 an average result, and nine a poor result. From a subjective point of view: 47 wrists presented an excellent result, five a good result, three a moderate result, and two a poor result. Overall, averaging the objective and subjective scores out of 100 points provided 28 excellent results, 19 good, six moderate, and four poor results. Of the ten moderate or poor results, there were four cases of grade III arthrosis and three cases of grade IV arthrosis; moreover, of these ten cases, four scaphoids were not healed. According to our modified score, the mean was 75 (out of a maximum of 100 points), with 16 poor results.

### Radiographic results

The carpal height index was a mean of 0.54 (range, 0.47-0.62) on the nonunion side. Of the 58 wrists, nine had an index under 0.51, for a reduced carpal height. The radiolunate angle was a mean of 4.8°. Twenty wrists had a radiolunate angle over 10° and therefore dorsal intercalated segmental instability (DISI). Thirty-six wrists (62%) were free of osteoarthritic degeneration or had minimal osteoarthritis. Of the six patients presenting grade IV osteoarthritis (based on the Alnot classification), two had no pain, three a low level of pain, and one experienced moderate pain.

### Correlations of the results

There was no correlation between the grade of osteoarthritis and the severity of pain at follow-up ($p = 0.7$). However, the severity of the osteoarthritis at follow-up was correlated with loss of mobility in extension ($p = 0.02$) but...
not with a loss of mobility in flexion ($p = 0.8$). The initial grade of nonunion had a highly negative influence on the result evaluated according to our score ($p = 0.0002$), notably from grade IIB. Similarly, the more advanced the nonunion grade, the more the grip strength had decreased ($p = 0.0001$). On the other hand, osteoarthritis grade was not correlated with strength at follow-up.

When the time between fracture and treatment was longer than 1 year, the Shah score was significantly lower ($p = 0.04$). However, the time lapse before surgical treatment did not influence the bone healing rate ($p = 0.9$) but was correlated with the severity of the osteoarthritis at follow-up ($p = 0.04$). The freshening technique used (reamer or curette) did not influence the functional score. In terms of functional score and bone healing rate, no significant difference was found depending on whether an inlay graft or an intercalary graft was performed. Similarly, the type of osteosynthesis did not have a significant effect on the bone healing rate, the functional score, or the morphological parameters of the carpus (radiolunate angle and carpal height). The length of time the wrist was immobilized had no significant effect on mobility at follow-up. Onset of proximal pole necrosis was harmful to healing since none of the necrotic areas had healed ($p = 0.0001$). Osteoarthritic degeneration was more severe when nonunion persisted ($p = 0.0025$), with a correlation between the nonunion grade and DISI ($p = 0.002$): in grade IIB, only 61.9% of DISI cases at follow-up versus 15.8% of DISI at follow-up when the initial grade was IIA. The functional score was lower in cases with DISI, but this was not statistically significant. The carpal height index did not influence the functional score.

**DISCUSSION**

Our series could be criticized for the low number of patients seen at follow-up (55.3%), but this rate is found in other series analyzing the long-term results of scaphoid nonunion treatment [Stark et al. (11)]. This can be explained by the fact that these are young subjects with a high level of geographical mobility. The data from our series corresponds to other data in the literature [Carpentier et al. (12), Green (13), Hoang and Rombouts (14), Schneider and Aulicino (15)]: these were young patients (mean, 26.7 years), for the most part manual workers (55.2%), with a majority of men (87.3% men). The follow-up period in this series was relatively long (8.8 years), which provided an improvement in the reliability of the results of nonvascularized corticocancellous grafts. Forty-five patients (77.5%) did not have an immediate diagnosis of their scaphoid fracture; the main causes of nonunion stem first and foremost from diagnostic errors and mistakes in initial treatment [Gandin (16)].

Most authors do not use the functional score and are only concerned by whether the nonunion has healed [Merrell et al. (17)]. Yet patients do not complain directly of their nonunion but rather the consequences (pain, reduced mobility, reduced strength, etc.). We therefore deemed it important to use a means to evaluate function numerically. Although the Shah score seemed the best adapted, its imperfections encouraged us to weight it as a personal score: 1) In the objective score, Shah and Jones (10) used nuances for evaluating healing (none, fibrous union, partial bony union, complete bony union) that we found difficult to assess. Consequently, our score is limited to a two-point evaluation of healing (yes or no). 2) The Shah score only studies the flexion-extension arc, whereas the radioulnar inclinations, very often disturbed, must be evaluated. 3) In the subjective Shah score, patients are asked whether the reduction in mobility or strength are performance-limiting factors. We noted that patients find it difficult to answer these questions. On the one hand, patients do not know how to express what bothers them, and on the other hand, they have adapted to the problem because of the long duration of the problem and the progressive onset of symptoms. Adapting the functional score in this way was confirmed as valuable by the difference in the subjective score results, noted 92.7, whereas the objective score was only 79.9. Overall, as for Stark et al. (18), patients were on the whole satisfied, whatever the subjective result. We believe that it was better adapted to bring subjectivity down to 20% of the total score, as opposed to 50% in the Shah score.

Overall, nonvascularized corticocancellous grafts give excellent subjective results. Only four patients were not satisfied with the treatment. In terms of pain, all patients improved. Although the objective criteria are significant (healing, necrosis, osteoarthritis), they are not recognized as such by the patient, who places pain as the top criterion [Stark et al. (19)]. The results are less flattering considering that 54% of patients who had had an iliac graft presented substantial pain at the harvesting site in the immediate postoperative period. This iliac crest graft, which has a number of advantages such as easy harvesting, nevertheless has notable disadvantages: scarring, pain requiring heavy postoperative analgesia, and general anesthesia and its risks. For the same nonvascularized corticocancellous graft technique, harvesting nearby on the radial epiphysis should be recommended to avoid these disadvantages. The duration if immobilization did not influence flexion-extension mobility, which is generally reduced in our population compared to the healthy side. But in our series, immobilization was always a minimum of 1.5 months. Although stable osteosynthesis sometimes provides earlier mobility, it does not guarantee better mobility [Merrell et al. (17)]. Wrist strength was 89.2% of the healthy side’s wrist strength. The most advanced stages of nonunion and osteoarthritis were accompanied by a greater reduction in strength. It therefore seems desirable to proceed to diagnosis and treatment of scaphoid fractures early.
Thirty-four percent of the wrists showed a DISI deformity upon review. Hooning et al. (20) discuss the absence of a correlation between the DISI deformity and osteoarthritis, which is not confirmed by our series. Although Nakamura et al. (21) did not find that the quality of the reduction significantly influenced results, as Tomaino et al. (22) and Linscheid et al. (23) found, our series underscores that over the long term the correction of the DISI deformity is necessary for a good result. Linscheid et al. (23) showed that instability was invariably a source of limited mobility and pain. We did not find this direct correlation, but our series showed that persistence of a DISI deformity encouraged the onset of osteoarthritis, which was itself a source of a reduction in mobility in extension. In our series, correcting the DISI deformity indirectly allowed maintenance of mobility in extension. Persistence of a DISI deformity in 20 wrists could be explained by it not being recognized on an old series with operators who at the time were not specialized in surgery of the hand. This spatial correction re-establishing the height of the scaphoid is only possible with an anterior corticocancellous graft, and not simply cancellous [Nakamura et al.(24)].

Our series included three grade IIIA and IIIB wrists. Two of these patients had a poor result, and the third a moderate result. The grade IIIB patient had the poorest score of our series and at follow-up presented grade IV degenerative osteoarthritis; the other two patients presented grade III osteoarthritis. Grades IIIA and IIIB are stages where the osteoarthrosis is already substantial, where palliative treatment would have been better adapted than grafting: partial arthrodesis of the wrist, resection of the first row of carpal bones, or resection of the proximal pole [Trumble (25)]. Healing alone does not resolve carpal lesions that are too advanced. At follow-up, 62% showed little or no osteoarthrosis. The onset of osteoarthritis is also correlated with the time between fracture and surgical treatment. We observed 81% healing, which corresponds to the results in the majority of series in the literature. Of the 11 patients who did not heal, seven presented proximal pole necrosis. This technique must therefore be avoided if there is necrosis, or the patient informed of the higher failure rate. It seems necessary to search for this necrosis preoperatively using MRI [Morgan et al. (26)], since radiographic evaluation is not sufficiently reliable [Green (13)], which should be done at the least doubt or for all proximal fractures. If necrosis is discovered preoperatively, 50%-100% of nonvascularized grafts do not heal [Trumble et al. (25)]. Green (13) suggested checking preoperatively for vascularization of the proximal pole, and, in case of necrosis, a vascularized graft should be used. In addition, healing is also influenced by the stage of nonunion. In our series, the time lapsed between fracture and surgery did not influence healing. Other series, however, have shown an influence on healing [Nakamura et al. (21)]. Contrary to the series presented by Nakamura et al. (21), screw fixation in our study did not provide better results. This is probably explained by the less frequent use of double-thread screws. In our series, these screws provided compression with control of scaphoid reduction. Other means of achieving osteosynthesis are recommended: blade plate systems, compression-staple fixation [Huene and Huene (27), Korkala et al. (28)]. However, these are highly bulky osteosynthesis options, with more limited indications.

Lindström and Nystrom (29) showed that 100% of nonunions, even asymptomatic, evolved toward symptomatic osteoarthritis. All nonunions should therefore be treated surgically, even asymptomatic ones, as early as possible, for better long-term results. Alnot (2) reached the same conclusion at the SOFCOT symposium. Nonvascularized grafts have the advantage of the relative simplicity of the technique, reliability (between 70% and 97% healing, depending on the series), and sufficient follow-up now confirms these results. These grafts have the disadvantage of poor results in cases of necrosis of the proximal pole, the consequences on the graft harvest site (iliac crest most of the time) that are responsible for postoperative pain and require general anesthesia and a healing period averaging 3 months. In the last few years, progress in microsurgery has seen the appearance of vascularized grafts (free or pedicled). This should push back the limits of conservative treatment in cases of proximal pole necrosis of the scaphoid if this vascularized graft allows revascularization.

References


