

Scaphoid Nonunion: Herbert Screw Fixation through Dorsal Approach

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Purpose: To evaluate the clinical and radiographic outcomes of scaphoid nonunion patients who had treated by open reduction and internal fixation with Herbert screw through dorsal approach.

Methods: We reviewed prospectively a series of 102 consecutive patients with scaphoid nonunion (Mack-Lichtman stage I, II, III). All patients were managed with open reduction with dorsal approach and internal fixation with a Herbert screw and additional K-wires. Exclusion criteria included conservative treatment, percutaneous fixation, scaphoid nonunion advanced collapse wrist. There were 94 male and 8 female with an average age of 28 years (range, 13–65 years). The mean follow period was 35 months (range, 12–96 months). Postoperative radiographs were reviewed to assess the fracture union, carpal alignment, and screw position. Functional results were evaluated by modified Mayo wrist score.

Results: Ninety-eight of 102 patients (96.1%) showed radiographic union at an average time of 12.7 weeks. Modified Mayo wrist score was 87.5 points in an average. Ninety-two of 102 patients (91.3%) showed more than good results. There was no major complications. There was no statistically significant difference between the preoperative and postoperative radiolunate angle, scapholunate angle, or height to length scaphoid ratio.

Conclusion: Herbert screw fixation through dorsal approach was a reliable method for patients of scaphoid nonunion to achieve bony union with high functional scores and without major complications.

Keywords: Scaphoid, Nonunion, Dorsal approach, Herbert screw

INTRODUCTION

Scaphoid nonunions present a challenging problem because of the geometry of the fracture and vascular pattern of the scaphoid. Natural history of the scaphoid nonunion was well known. A gradual onset of arthritic changes were noted beginning between 5 and 10 years after nonunion. The initial abnormalities were confined

to the scaphoid and consisted of cyst formation, fracture site resorption, and sclerosis at the fracture margins. Subsequently, pointing of the radial styloid and narrowing of the radioscapoid articulation became evident. And then, progressive degeneration ensued, with further periscaphoid involvement.

The simple or displaced nonunion can be treated by open reduction and internal fixation with or without

bone graft. When considering the appropriate way to treat scaphoid nonunion, we can use either volar or dorsal approach. Volar approach is most commonly used approach. The great advantages of the volar approach is that it provides excellent visualization of the entire volar surface of the bone. However, in a recent cadaveric study, Chan and McAdams¹ found that the dorsal approach permits screw placement closer to the central axis compared with the volar approach. Central placement of the screw is advantageous biomechanically, with greater stiffness and load to failure.

So we reviewed prospectively the radiographic and functional outcomes in a consecutive series of scaphoid nonunion patients who had Herbert screw fixation through dorsal approach.

MATERIALS AND METHODS

We reviewed prospectively a series of 102 consecutive patients with scaphoid nonunion (Mack-Lichtman stage I, II, III) and followed more than 1 year during last 10 years. All patients were managed with open reduction with dorsal approach and internal fixation with a Herbert screw and additional K-wires. Styloidectomy was also performed for 6 patients because of radioscapoid degeneration (Table 1). The study group included 94 male and 8 female patients with an average age of 28 years (range, 13–65 years). Sites of nonunion included distal 1/3 (6 cases, 5.8%), waist (88 cases, 86.4%), and proximal 1/3 (8 cases, 7.8%). The mean follow up time for this group was 35 months (range, 12–96 months). Exclusion criteria included conservative treatment, percutaneous fixation, scaphoid nonunion advanced collapse (SNAC) wrist.

1. Assessment of patient outcomes

Posteroanterior (PA), lateral and 30 pronation PA X-rays were used to assess the radiologic consolidation. Consolidation was accepted when there was disappearance of the nonunion line, evidence of bone trabeculae crossing the nonunion line, absence of the gap at the fracture site, absence of the lucency around the implant and no signs of internal fixation failure^{2,3}. Radiologic study included change of carpal alignment, progress of arthritic change.

Wrist range of motion and grip strength were measured in both limbs at the final follow-up. Range of motion was checked and grip strength parameters were converted into a percentage of the contralateral side for each patient. Grip strength of the nondominant hand was multiplied by 1.07 before comparing it to that of the dominant hand. Pain and tenderness at the final follow-up visit and return to previous occupation also were obtained. A modified Mayo wrist score⁴ was used for functional assessment. We compared the preoperative and postoperative radiolunate angle, scapholunate angle, and height to length ratio of the scaphoid, as described by Bain et al.⁵ Scaphoid length was measured preoperatively and postoperatively to rule out any shortening following screw compression, which might prove detrimental to normal carpal mechanics. Central versus eccentric screw position, as based on previously established criteria by Trumble et al.⁶, was assessed on anteroposterior, lateral, and dedicated scaphoid views.

A paired sample t test was used to compare. A difference was considered to be statistically significant when $p < 0.05$.

2. Surgical technique

The patient is placed in a supine position with the affect-

Table 1. Method of treatment

Scaphoid	Open reduction and internal fixation				Total
	Only	Bone graft (radius)	Bone graft (iliac)	Bone graft radial styloidectomy	
Nonunion I	41	3	-	-	44
Nonunion II	20	17	15	-	52
Nonunion III	-	-	-	6	6
Total	61	20	15	6	102

ed hand on the C-arm. The procedure is carried out under regional anesthetic block. The upper arm tourniquet is inflated. The forearm is pronated and a longitudinally curved skin incision that is approximately 3 cm in length is placed beginning at the proximal aspect of Lister's tubercle. The extensor retinaculum between second and third extensor compartment is incised. By placing retractors, the extensor carpi radialis longus tendon is retracted radially and the extensor carpi radialis brevis and the extensor pollicis longus tendons are retracted ulnarly. A longitudinal capsulotomy is performed along the long axis of the incision. Now we can expose the articular surface of the radius, radioscapoid joint, scapholunate interval and scaphoid nonunion site (Fig. 1). Reduction of the nonunion site is attempted. To help the reduction, the carpus is distracted manually via longitudinal traction on the index and long fingers and then manual reduction is facilitated. When a satisfactory reduction has been achieved, provisional fixation is obtained with two 0.045 K-wires which were inserted eccentrically from the dorsal ridge of the radius to slightly volar to the central axis of the scaphoid axis. Using the K-wires as lever-arm, a scaphoid is volar flexed. Guide K-wire is then inserted in the central axis of the scaphoid under the C-arm control. To determine the appropriate

screw length, an identical second guide wire is applied to the proximal cortex of the scaphoid. The difference between the two wires is measured and the screw length is determined. After remove the guidewire, drilling and tapering for the fixation of the Herbert screw was done. And then Herbert screw fixation is inserted with a free hand technique. Final position of the Herbert screw is checked with C-arm. Two K-wires which were fixed eccentrically is retracted volarly but not removed for additional stability. The end of the K-wires were left on the volar skin. These K-wires are removed after 8 weeks operation at the time of cast off (Fig. 2).

In case of cyst formation, we can do additional bone graft through dorsal window after fixation of the scaphoid.

When scaphoid nonunion is accompanied with sclerotic margin or humpback deformity, 0.045 K-wire are inserted perpendicularly to the central axis of the scaphoid into the proximal and distal scaphoid fragments. These two K-wires can be used to assist reduction and handling of the scaphoid. Decortication of the sclerotic margin with electric saw until fresh bone is exposed is made. Reduction of the nonunion site is attempted with assist of the joystick K-wires. After confirm the reduction with the C-arm. Insertion of the iliac bone graft

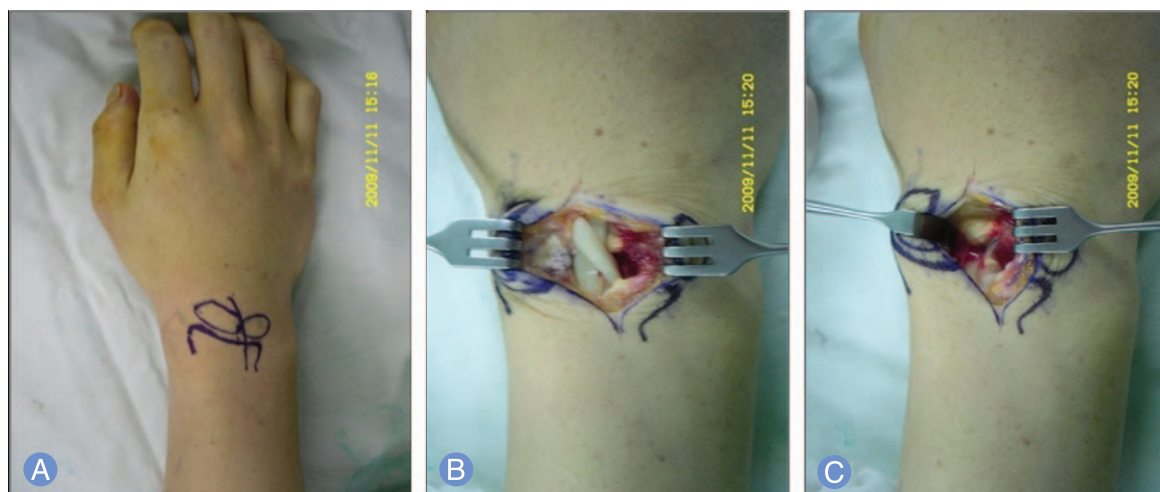


Fig. 1. (A) Skin incision. (B) The extensor retinaculum between second and third extensor compartment is incised. (C) By placing retractors, the extensor carpi radialis longus tendon is retracted radially and the extensor carpi radialis brevis and the extensor pollicis longus tendons are retracted ulnarly. A longitudinal capsulotomy is performed along the long axis of the incision.

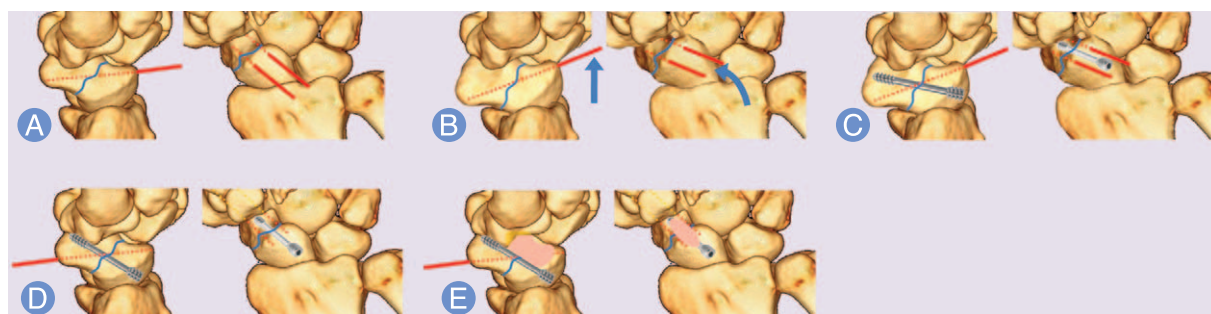


Fig. 2. (A) When a satisfactory reduction has been achieved, provisional fixation is obtained with two 0.045 K-wires which were inserted eccentrically from the dorsal ridge of the radius to slightly volar to the central axis of the scaphoid axis. (B, C) Using the K-wires as lever-arm, a scaphoid is volar flexed for the screw which is then inserted in the central axis. (D) Two K-wires which were fixed eccentrically is retracted volarly but not removed for additional stability. (E) In case of cyst formation, we can do additional bone graft through dorsal window after fixation of the scaphoid.

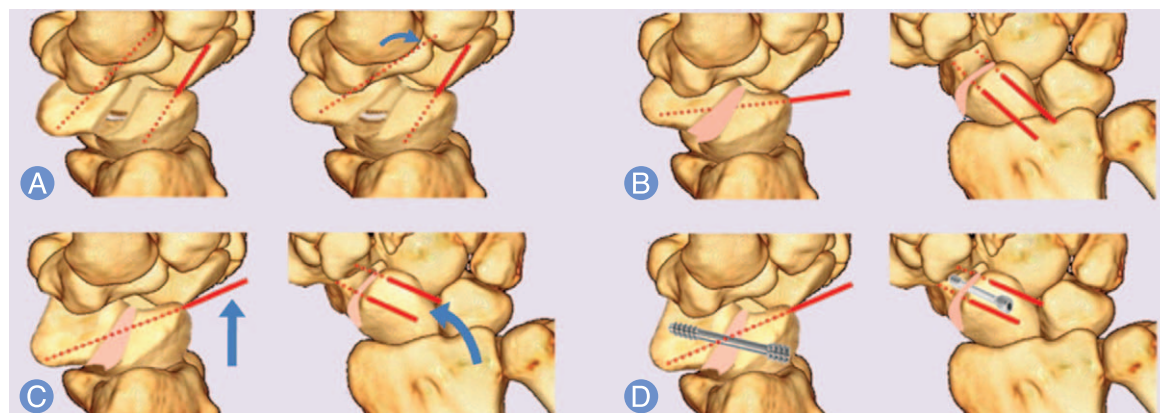


Fig. 3. (A) 0.045 K-wire are inserted perpendicularly to the central axis of the scaphoid into the proximal and distal scaphoid fragments. Reduction of the nonunion site is attempted with assist of the joystick K-wires. (B) After insertion of the iliac bone graft into the gap, provisional fixation with two K-wires which were inserted eccentrically as the same procedure as simple nonunion. (C) Using the K-wires as a lever-arm, the scaphoid is volar flexed. (D) Herbert screw fixation is done in the central position with a free hand technique.

into the gap. Provisional fixation with two K-wires which were inserted eccentrically as the same procedure as simple nonunion. Using the K-wires as a lever-arm, the scaphoid is dorsiflexed. Herbert screw fixation is done in the central position with a free hand technique. Two provisionally fixed K-wires retracted volarly but left for additional stability (Fig. 3).

Postoperatively, the patient is immobilized in a short arm plaster splint and is advised to elevate the hand the first days for control of swelling. At 2 weeks, the patient returns for suture removal and short arm thumb spica cast. At 8 weeks postoperation, cast and K-wires were removed. Range of motion exercises and occupational

therapy are begun. Fracture healing is assessed at 2, 4, 8, 12, and 16 weeks postoperatively with routine plain radiographs. The duration of follow-up depends on radiographic fracture healing and clinical evaluation.

RESULTS

Ninety-eight of 102 patients (96.1%) in the scaphoid nonunion progressed to radiographic union without complication (Table 2). The average time to union was 12.7 weeks (range, 8–26 weeks). Overall, the final range of motion of the wrist averaged 61° (range, 42°–70°) of volar flexion, 47° (range, 35°–60°) of dorsiflexion, 16° (range,

10°–20°) of radial deviation, and 27° (range, 22°–30°) of ulnar deviation. In 92 of 102 patients (90%), grip strength parameters were converted into a percentage of the contralateral side were over 85%. 9 patients (9%) had 70% to 84% grip strength parameter compared with contralateral side and 1 patient (1%) had 50% to 69% grip strength parameter compared with contralateral side. The mean grip strength was 38 kg at the final follow-up evaluation, which was approximately 91% of the uninvolved wrist. Paired t-test analysis showed no significant difference ($p>0.05$) in grip strength between the injured and uninjured extremity at the final follow-up evaluation.

Eighty-nine patients (87%) were pain free and asymptomatic at final follow-up. Thirteen patient (13%) had mild pain with vigorous activities or pain only with weather changes. No patient had moderate pain with activities of daily living or pain at rest. Ninety-five employed patients (93%) eventually were able to return to their preinjury employment without restrictions and 7 employed patients (7%) returned to their employment with mild restrictions.

According to the more stringent modified Mayo wrist score system, 102 the functional results were excellent for 60 patients (58.9%), good for 32 patients (32.4%), fair for 8 patients (7.8%), and poor for 2 patient (1.9%) (Table 3).

Twelve patients that performed styloidectomy and 3 patients that performed ligament repair had satisfactory

results similarly. No statistically significant difference was found between the preoperative and postoperative radiolunate angle, scapholunate angle, or height to length scaphoid ratio, as measured by either independent reader ($p>0.05$). There were no perioperative complications. None of the patients showed radiographic signs of arthrosis during the study period. There were no complications related to Herbert screw (i.e., migration or loosening). None of the patients showed stiffness of the fingers or thumb, nor did they develop complex regional pain syndrome. Screw position relative to the central axis of the scaphoid as defined by Trumble et al.⁶ was evaluated on postoperative AP, lateral, and dedicated scaphoid radiographs. 98 of 102 patients (96%) showed a central screw position on the AP and lateral views. 92 of 102 percent (90%) of patients showed a central screw position on the dedicated scaphoid view.

DISCUSSION

Due to anatomical properties including tenuous vascular supply, joint fluid dilution, and the inability to form callus, as well as biomechanical properties, such as high shear stress and displacement of fragments, delayed unions and nonunions are not uncommon. Delayed treatment and an inadequate period of fixation are also responsible for scaphoid nonunion⁷. It is known that the nonunion rate of scaphoid fracture is 5% to 10% with non-surgical treatment^{2,8}. Established nonunion, if left untreated, will progress to osteoarthritis and impair the function of the wrist joint^{7,8,9}. Therefore, in most instances, nonunions of the scaphoid are managed by surgery. However, the treatment of scaphoid nonunions is trouble-some, with reported failure rates between 25% and 45%^{10,11}. The key points of successful surgery for scaphoid nonunions include achieving union of the fracture, correcting the deformities, restoring anatomical alignment, and recovering the function of the wrist¹².

There is more than one way to do the surgery (open volar approach or open dorsal approach, percutaneous approach). The location and type of fracture determine which approach allows the best screw placement^{13,14}. In

Table 2. Radiologic union rate

Mack-Lichtman stage	No. of union (%)
Stage I	44/44 (100)
Stage II	50/52 (96.1)
Stage III	4/6 (66.6)
Total	98/102 (96.1)

Table 3. Modified Mayo wrist score

Score/Stage	Stage I	Stage II	Stage III	Total (%)
Excellent	33	27	-	60 (58.9)
Good	10	20	2	32 (32.4)
Fair	1	5	2	8 (7.8)
Poor	-	-	2	2 (1.9)
Total	44	52	6	102 (100)

Mean modified Mayo score: 87.5 points.

nondisplaced waist nonunions perpendicular to the long axis of the scaphoid, the approach depends on the surgeon's preference. Proximal pole nonunions are more easily managed with a dorsal approach, and distal nonunions with a volar approach. Open techniques for fixation are generally indicated for scaphoid nonunions¹⁵. The volar approach is typically used for distal third or mid-waist nonunions of the scaphoid. This approach is particularly useful to correct a humpback deformity of the scaphoid. The important dorsal blood supply is left undisturbed, and a good view of the volar surface of the scaphoid is facilitated. But volar approaches may jeopardize the already tenuous blood supply to the proximal pole, resulting in avascular necrosis. Volar open approaches necessitate division of the important volar radiocarpal ligaments. Garcia-Elias et al.¹⁶ reported a significant increase in scapholunate and lunocapitate angles following a volar approach for fixation of scaphoid fractures when the radiocapitate and radiolunate ligaments were divided. Most importantly, the disadvantage is that the screw may be placed slightly oblique to a fracture line in the mid-waist portion of the scaphoid. If a volar approach is used, central screw placement is hindered by the volar aspect of the trapezium. Investigators have attempted to identify optimal guidelines for screw placement, including manipulation and partial excision of the trapezium^{17,18}. The additional dissection may cause attendant problems including vascular compromise, scaphotrapezial instability, and degenerative changes^{19,20}.

Although there are articles showing excellent results with a dorsal percutaneous approach for nondisplaced waist nonunions²¹, recent reports highlight the potential risks of this approach. The anatomical structures at risk (e.g., the posterior interosseous nerve, extensor digitorum communis to the index, and extensor indicis proprius)²² and complications (e.g., hardware problems, nonunion, extensor pollicis longus rupture, and screw malpositioning) might be more common than previously assumed^{23,24}. The disadvantage of the dorsal approach is that, as the wrist is hyperflexed, the unstable scaphoid fracture may displace to create a humpback deformity.

A open dorsal approach is most useful for proximal

pole fractures and preserves the volar carpal ligaments. In addition, exposure of the scapholunate ligament is facilitated to address any injury there. This approach allows more central placement of the screw down the long axis of the scaphoid and avoids any possibility of damaging the important anterior stabilizing radioscaphocapitate and radioscapholunate ligaments^{25,26}, allowing earlier postoperative wrist mobilization. In addition, central placement of the screw in the proximal pole fragment, as described by Trumble et al.²⁷, is more predictable using a dorsal approach, allowing for more rigid fixation. These findings are in concordance with Chan and McAdams¹, who showed more accurate and reliable central axis screw placement with the dorsal versus the volar approach in a cadaveric model. A study showed central screw placement to be stronger and to have greater stiffness and increased load to failure compared with eccentrically placed screws. Thus, a centrally located screw reduces the likelihood of screw failure²⁸. The main advantage of our approach is the ability to reliably and safely insert the screw along the central scaphoid axis. Using two K-wires that is inserted more dorsally to the central axis as lever-arm, it is possible for guidewire to insert into the central axis of scaphoid easily. Generally, the disadvantage of the dorsal approach is that, as the wrist is hyperflexed, the unstable scaphoid fracture may displace to create a humpback deformity and put the extensor tendons with several anatomic structures at risk²². Because of K-wire levering technique, we can fix the screw without hyperflexion of wrist. Consequently, 98 of 102 patients (96%) showed a central screw position on the AP and lateral views without complications. 92 of 102 percent (90%) of patients showed a central screw position on the dedicated scaphoid view. Although the association of central screw position with higher rates of union has not been accepted definitely, our results showed higher union rates with higher central position of screw. Ninety-eight of 102 patients (96.1%) in the scaphoid nonunion progressed to radiographic union and the average time to union was 12.7 weeks. In addition, our results showed favorable range of motion and restoration of grip strength. Patients returned to

their employment with no restrictions and according to the modified Mayo wrist score system, most patients were above good grade.

Screw fixation provides more successful union rates than K-wire fixation but which of the screw types provides better compression remains debatable²⁹⁻³¹. Most previous studies suggest that the Acutrak screw generates greater compression. But a study shows that there is no significant difference between the Acutrak and cannulated Herbert screws with respect to functional outcome, consolidation rate and time to consolidation in the treatment of scaphoid nonunion. It seems that difference in compressive force between these screws does not influence the outcome³². Apart from selection of the screw type, bone grafting and rigid fixation into the central axis are required to achieve union.

The usual treatment for scaphoid nonunion is conventional bone grafting, with or without bony fixation. Satisfactory bone union rates ranging from 80% to 90% have been reported by some authors³³; but failure rates as high as 65% have been described by others^{10,34}. Most of these failures have been related to fractures of the proximal pole or avascular necrosis of the proximal fragment. We treated that vascularised bone grafting is mandatory whenever there is a non-vascularised sclerotic fragment. On the other hand, in patients with well vascularised fragments, conventional non-vascularised bone graft from the distal radius or ilium can be used. Iliac crest has been considered the gold standard for corticocancellous grafting in unstable scaphoid nonunions because of the quality of osteoprogenitor cells obtained and the biomechanical properties of the graft^{35,36}.

In arthroscopic evaluation of displaced and nondisplaced scaphoid waist fractures, they found that 71% had associated acute scapholunate (SL)-ligament injuries and 24% had a complete SL ligament rupture³⁷. The overall number of ligament injuries is high compared to findings in previous studies involving arthroscopic examination, where incidences of between 14% to 50% have been reported^{38,39}. A high incidence of SL ligament injuries found in scaphoid nonunions has raised the possibility of an association between the 2 injuries⁴⁰. We believe that

the combination of these 2 lesions is clinically important because it might lead to an increased risk of developing scaphoid nonunion. We recommend dorsal approach to assess and treat associated intrinsic ligament injuries at the same incision of screw fixation.

Styloidectomies have been unsatisfactory as isolated procedures for SNAC arthritis, but have enjoyed success when combined with bone grafts, with or without internal fixation, for stage I SNAC arthritis. Using limited dorsal approach, styloidectomy can perform for mild radioscapoid degeneration (stage III) at the same time.

CONCLUSION

We found Herbert screw fixation using a dorsal approach was a reliable method for patients to achieve bony union with high functional scores and without major complications. Furthermore, the dorsal approach enable to visualize any associated scapholunate ligament injury, have a radial styloidectomy for patient with arthritis, and harvest cancellous bone graft or vascularized pedicled bone graft from distal radius. With the dorsal approach, distal nonunions of scaphoid are more easily managed in addition to proximal pole and waist fractures.

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배측도달법을 이용하여 Herbert 나사못으로 내고정을 시행한 주상골 불유합의 치료

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목적: 주상골 불유합 환자에서 배측도달법을 이용하여 Herbert 나사못으로 내고정을 시행한 후 임상적, 방사선학적 결과를 알아보고자 하였다.

방법: 주상골 불유합(Mack-Lichtman stage I, II, III)으로 배측도달법을 이용하여 Herbert 나사못과 추가적인 K-강선으로 내고정을 시행받은 환자 102명을 대상으로 전향적으로 연구하였다. 보존적 치료, 경피적 나사 고정술을 받거나 주상골 불유합 진행성 붕괴(scaphoid nonunion advanced collapse)가 있었던 예는 제외하였다. 남자가 94예 여자가 8예였으며, 평균 연령은 28세(범위, 13-65세), 평균 추시 기간은 35개월(범위, 12-96개월)이었다. 수술 후 방사선 검사를 통해 골유합, 수근골 정렬, 나사못의 위치를 평가하였다. 기능적 결과는 modified Mayo wrist score를 통해 평가하였다.

결과: 102예 중 98예에서 방사선학적으로 골유합을 얻었으며 평균 기간은 12.7주였다. Modified Mayo wrist score를 이용한 기능적 평가에서 평균 87.5점으로 102예 중 92예에서 우수 이상의 결과를 보였으며 주요 합병증은 발생하지 않았다. 수근골 정렬은 수술 전 후 유의한 차이가 없었다.

결론: 배측도달법을 이용한 Herbert 나사못 내고정술은 높은 골유합률 뿐 아니라 기능적으로도 우수한 결과를 보여 주상골 불유합 환자에서 유용한 방법으로 생각된다.

색인단어: 주상골, 불유합, 배측도달법, Herbert 나사못

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