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## 불량한 예후 인자를 가진 주상골 불유합의 치료에서 내측 대퇴 과두 혈관화 골 이식술의 효용성

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## Free Vascularized Medial Femoral Condyle Bone Graft for Scaphoid Nonunion with Poor Prognosis Factors

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**Purpose:** Authors attempt to evaluate the clinical and radiographic results of the treatment of scaphoid nonunion with poor prognostic factors with the free vascularized medial femoral condyle bone graft.

**Methods:** We operated on eight patients with avascular necrosis or prolonged nonunion of the scaphoid between January 2016 and July 2019. Wrist motion in terms of flexion, extension, and ulnar and radial deviation, a visual analogue scale (VAS), the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, the modified Mayo wrist score, scapholunate angle, and carpal height index were collected in the clinic setting preoperatively and at the latest follow-up in all patients.

**Results:** Eight patients with union achieved correction and maintenance of both scapholunate angle and carpal height index. The VAS pain scores significantly improved from 5.1 preoperatively to 3.3 postoperatively. There was a statistically significant improvement in the average DASH score at the final follow-up. Scapholunate relationships in the reconstructed wrists remained almost unchanged, with average scapholunate angles of 49.7° before surgery and 47.0° at the latest postoperative follow-up. There was no statistical significance between the number of poor prognosis factors and the time to union, but there was a positive correlation.

**Conclusion:** It could help surgeons manage the scaphoid nonunion associated with poor prognostic factors such as avascular necrosis, carpal collapse (posttraumatic arthritis), prolonged nonunion, and failed prior scaphoid nonunion surgery.

**Keywords:** Avascular necrosis of bone, Scaphoid nonunion, Free vascularized medial femoral condyle bone graft

## INTRODUCTION

Scaphoid nonunions occur in an estimated 15% of the scaphoid fractures. Among these, avascular necrosis (AVN) is seen in approximately 3% of all

scaphoid fractures, mostly seen among proximal pole fractures [1]. The retrograde blood supply to the proximal pole of scaphoid bone makes it susceptible to high nonunion rate and AVN after fractures [2]. The treatment of nonunion of the scaphoid with AVN is still a challenge for surgeons [3].

Several surgical procedures have been developed for the treatment of nonunion, including vascularized bone graft (VBG) and non-VBG, with or without internal fixation [4-7]. Although the Russe bone graft technique has provided the mainstay of operative treatment for scaphoid nonunion, non-VBG has been less beneficial in cases of AVN [6]. A meta-analysis of Merrell et al. [8] demonstrated that VBG showed a significantly better union rate (88%) compared to traditional bone graft (47%). Recent studies have established the efficacy of VBG for the scaphoid nonunion complicated by AVN with a higher union rate and shorter time to union [6,9,10].

VBG can be further classified into pedicled or free VBG. Common pedicled VBG options are 1, 2 intercompartmental supraretinacular artery pedicle (Zaidenberg), and pedicle on the volar carpal artery (Mathoulin). The more common free VBG choices are iliac crest and medial femoral condyle (MFC) graft [1,2,6,11]. Pedicle grafts are often limited in location, dimension, and length of the pedicle. Free VBGs are maneuverable grafts for correcting carpal collapse or other deformities and have the advantage of overcoming the limitations that may be manifested in pedicled grafts. In addition, VBG can fill in larger skeletal defects with harder bones. Therefore, among these, MFC VBG can be a good option for the treatment of scaphoid nonunion with poor prognostic factors such as proximal pole AVN, a delay in a presentation, or previous nonunion surgery [4,9,12-14]. The purpose of this study was to evaluate the clinical and radiographic results of MFC VBG in the treatment of scaphoid nonunion with poor prognostic factors.

## MATERIALS AND METHODS

### 1. Materials

The present study is a retrospective case-series study conducted under the official approval of the Institutional Review Board of Yeungnam University Medical Center (No. YUMC 2020-04-045). Informed consent was taken from all patients, and the study complied with all necessary data protection protocols. From January 2016 to July 2019, scaphoid nonunion and AVN were treated surgically by one surgeon. MFC VBG for the scaphoid nonunion and AVN with a minimum of 1-year follow-up was analyzed. All patients had established (at least 6-month duration) nonunion.

The following inclusion criteria were applied: (1) scaphoid nonunion with AVN or with scaphoid deformity or carpal malalignment, (2) prolonged nonunion over 3 years, (3) persistent nonunion despite previous surgery, and (4) scaphoid nonunion advanced collapse stage I.

The exclusion criteria were as follows: (1) acute fractures, (2) compound fractures, (3) inadequate clinical records or incomplete follow-up data, (4) patients with congenital deformity (bipartite scaphoid, congenital aplasia, and hypoplasia of scaphoid), (5) patients with healing disorders such as diabetes or vascular disease, and (6) severely morbid patients.

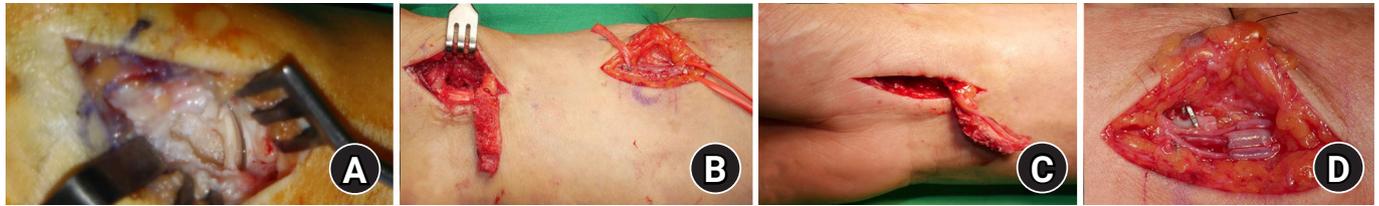
AVNs were confirmed by histological examination. All patients had preoperative X-ray and magnetic resonance imaging (MRI) evidence of AVN. The signs of AVN in the plain radiograph include sclerosis with occasional fragmentation and collapse. Also, MRI with marked low signal intensity on T1-weighted images. When the absence of intraoperative punctate bleeding after deflation of tourniquet was confirmed during operation, we performed an intraoperative biopsy of pathological examination.

### 2. Surgical technique

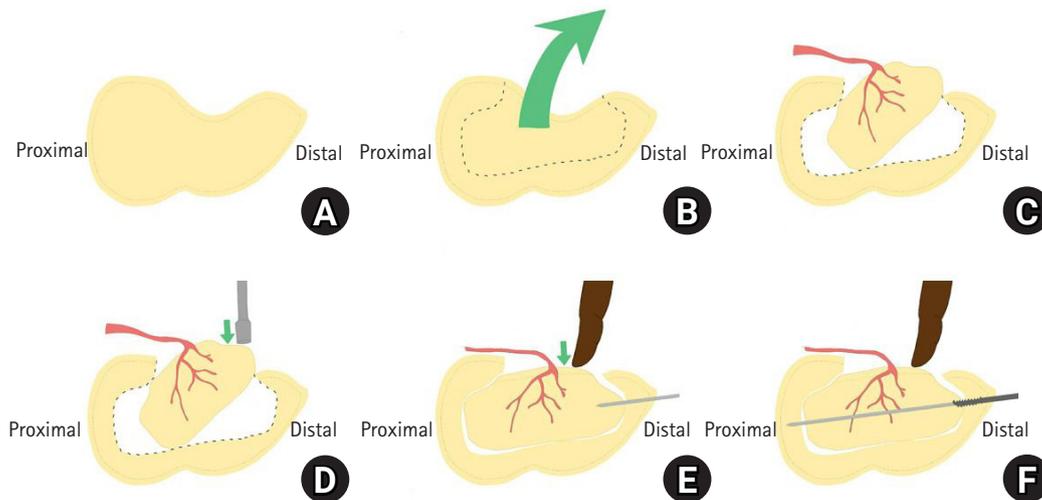
All operations were performed under general anesthesia. The patients were positioned supine with the arm on a radiolucent table. The arm and the opposite side leg were prepared with antimicrobial solution and draped in a sterile manner. A bump was placed under the knee to maintain the figure-eight position with knee flexion and hip external rotation. The arm was exsanguinated with an Esmarch bandage before the tourniquet was inflated. A standard longitudinal approach to the wrist was performed through the volar (Russe) incision on the floor of the flexor carpi radialis tendon sheath. The radioscaphocapitate ligament was divided radial to the long radio-lunate ligament, allowing joint exposure.

#### *Scaphoid preparation*

Any fibrous tissue in the area of the scaphoid nonunion was removed with a rongeur and curettes to allow adequate exposure of the nonunion site. When the nonunion site was exposed, an oval cortical window was made using a 3-mm diameter high-speed burr on the volar aspect of the proximal and distal pole of the scaphoid (Fig. 1A, B). We excavated as much necrotic bone as possible if encountered while leaving the dorsal cortex intact. The proximal and distal poles cavitated to prepare an adequate room to accept a corticocancellous strut graft (Fig. 2B). When the debrided surface of the proximal pole was sclerotic, we deflated the tourniquet and assessed the vascularity by the punctate bleeding. If punctate bleeding was not noticed after 2 to 3



**Fig. 1.** (A) Anterior (Russe) scaphoid exposure shows the nonunion site. When the nonunion site was exposed, an oval cortical window was made using a 3-mm diameter high-speed burr on the volar aspect of the proximal and distal pole of the scaphoid. (B) Intraoperative photos of debridement of the nonunion site at the scaphoid and preparation to accept the vascularized medial femoral condyle graft. (C) The graft was further shaped to fit the nonunion site. The periosteal surface attached to the pedicle should lie volar. (D) Vascular repairs were end-to-side to the radial artery and end-to-end to a vena comitans.



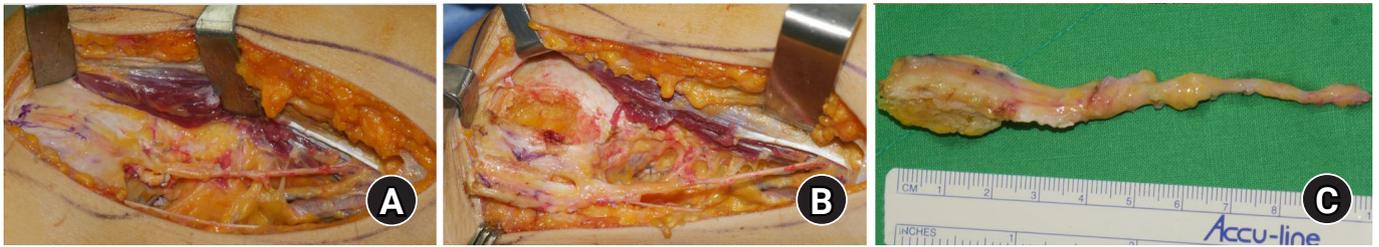
**Fig. 2.** (A) Lateral aspect of the scaphoid. (B) The surgeon excavated as much necrotic bone as possible if encountered while leaving the dorsal cortex intact. (C) The graft is inset obliquely into the scaphoid defect with the cortex facing palmar. (D) Push the distal part of the graft with the impactor. (E) To fit graft properly without rotation or extrusion of graft and vessels, the surgeon holds the distal part of the graft with the index finger during temporary fixation with guide wire. (F) A 3.0-mm partially threaded headless compression screw was inserted along the guide wire and the guide wire was removed.

minutes of observation, we confirmed AVN of the proximal pole and harvested the vascularized corticocancellous flap from the opposite side thigh.

#### *Free vascularized medial femoral condyle bone graft harvest*

Under tourniquet control, a longitudinal incision was made in the distal third of the medial thigh, in line with the posterior border of the femoral shaft, continuing distally centered upon the MFC. Dissection was carried through the subcutaneous tissue, using electrocautery. The vastus medialis fascia was incised sharply at its posterior aspect, and the muscle retracted properly exposing the medial genicular artery system distally, which is intimately associated with the periosteum (Fig. 3A). Proximal dissection was carried out to isolate the medial genicular pedicle containing the artery and vena comitans. The pedicle was traced back to the superficial femoral artery, and several cuta-

neous and muscular perforators were ligated in the process. Electrocautery was used to delineate a periosteal flap approximately twice as large as the bony defect, which was elevated while protecting its connection with the bony portion of the flap. The graft must not extend into the thick cortex at the diaphyseal/metaphyseal junction. A rectangle of sufficient size to fill the gap in the scaphoid is marked out, the periosteum sharply incised, and the bone cut with a micro sagittal saw and osteotomes (Fig. 3B). The periosteum associated with the transitional portion of the pedicle was elevated from the underlying bone (Fig. 3C). Bone void filler was not applied to the donor defect prior to layered wound closure. Additional bone graft can be harvested from the void in the distal femur if necessary to fill any cavity.



**Fig. 3.** (A) Preparation and harvesting of the medial femoral condyle graft. The vastus medialis fascia was incised sharply at its posterior aspect, and the muscle retracted properly exposing the medial genicular artery system. (B) A rectangular shape of sufficient size to fill the gap in the scaphoid is marked out, the periosteum sharply incised, and the bone cut with a micro sagittal saw and osteotomes. (C) The corticocancellous graft was harvested with its vascular pedicle.

#### *Graft in setting, fixation and vascular anastomosis*

The graft was further shaped to fit the defect in the scaphoid. The periosteal surface attached to the pedicle should lie volar (Fig. 1C). All patients were treated with a 3.0-mm partially threaded headless compression screws (Synthes, Solothurn, Switzerland) except two cases, which were fixed with Kirschner wires (K-wire). Fluoroscopy was used to confirm proper bone graft and pin positioning. Utmost care was taken intraoperatively not to damage or fracture muscle pedicle or its vessel. The graft is inset obliquely into the scaphoid defect with the cortex facing palmarly (Fig. 2C) and the surgeon pushes the distal part of the graft with the impactor (Fig. 2D). To fit graft properly without rotation or extrusion of graft and vessels, the surgeon holds the distal part of the graft with the index finger during temporary fixation with guide wire (Fig. 2E). A 3.0-mm partially threaded headless compression screw was inserted along the guide wire and the guide wire was removed (Fig. 2F). Vena comitans and the radial artery are exposed via prior Russe incision. The end-to-side vascular repairs were performed to the radial artery and end-to-end to a vena comitans (Fig. 1D). In the case of difficulty identifying healthy blood flow after the anastomosis, the end-to-side repair was changed to the end-to-end method. In patients with early scaphoid nonunion advanced collapse arthrosis limited to the radial styloid, radial styloidectomies were performed.

### **3. Clinical and radiographic evaluation**

For the clinical evaluation, wrist motion in terms of flexion, extension, and ulnar and radial deviation, a visual analogue scale (VAS), the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, and the modified Mayo wrist scores (MMWS) were collected in the clinic setting preoperatively and at the latest follow-up in all patients. All patients underwent preoperative radiographic evaluation with plain radiographs including scaphoid view. And it was supported by computed

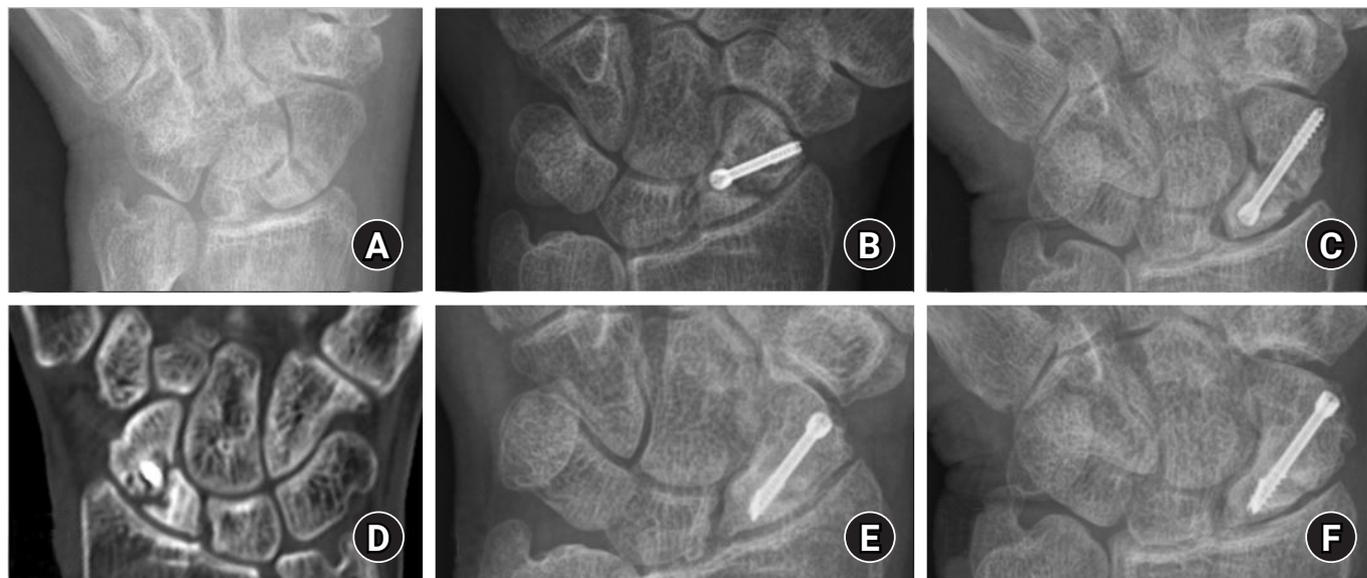
tomography (CT) scans and MRI to diagnose nonunion and AVN of the scaphoid. The scaphoid nonunions were categorized according to Herbert classification that was commonly used. The scapholunate angle, the angle between the long axis of the scaphoid and the mid axis of the lunate on the sagittal imaging of the wrist, was measured. The carpal height was defined as a distance between the distal articular surface of the capitate to the distal articular surface of the radius. The carpal height index [15] was calculated by dividing the carpal height by the length of the third metacarpal using a true anteroposterior radiograph. Standardized radiographs were checked at the first visit and every 4 weeks after surgery until healing was confirmed to access alignment maintenance and healing of scaphoid nonunion. The healing was defined as the presence of bridging trabeculae on plain radiographs (Fig. 4) and ultimately confirmed with the CT scans. The radiologic parameters were evaluated at 6 and 12 months after surgery and the latest follow-up.

### **4. Postoperative rehabilitation protocol**

All patients participated in the same postoperative rehabilitation protocol, which consisted of a short-arm thumb spica cast for approximately 6 weeks, after which 4 weeks of removable brace with active and passive range of motion (ROM) exercise. At 3 months, patients were advanced to strengthening and light daily activities; and at 6 months, they returned to usual activities and restarted manual work. Contact sports and heavy labor were avoided for 1 year depending on the individual's functional recovery. Patients started weight-bearing and walking exercises immediately after easing acute pain on the lower extremity.

### **5. Statistical analysis**

Continuous data were presented as mean and standard deviations. Wilcoxon signed-rank tests were used to compare the



**Fig. 4.** (A) Scaphoid view of the wrist of a 51-year-old man, showing an scaphoid fracture. (B) Anteroposterior and (C) scaphoid view of wrist at 10 month after 1st operation in other hospital, showing an established scaphoid nonunion, sclerotic change around the fracture site. (D) Postoperative computed tomography at 10 month after 1st operation in other medical center, showing sclerotic change. (E) Anteroposterior and (F) scaphoid view of wrist 1-year after the last operation, showing achievement of union, correction, and maintenance of carpal height index.

variables: ROM, VAS, DASH scores, MMWS, scapholunate angle, and carpal height index. The correlation analysis between the number of poor prognosis factors and time to union was analyzed by using the Spearman rho test. Statistical analyses were conducted using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). The p-values of  $<0.05$  were considered significant.

## RESULTS

Nine patients who were symptomatic and had nonunion or AVN of scaphoid were prospectively enrolled in this study. One patient was excluded due to incomplete follow-up data. Ultimately, eight patients were enrolled in this study (Table 1). The average follow-up period was 18.25 months (range, 12–32 months). Among the patients, five were men and three were women. Their mean age of the patients was 50.0 years (range, 26–64 years).

Six of the eight cases were the right wrist and two were left wrist. Five cases were the dominant wrist. Three of the patients were laborers, three were housewives, one was a farmer, and one was a student. The mode of injury for seven patients was fall on hyperextended wrist and one had injury following punching. Seven patients had previous failed attempts at reconstruction with nonvascularized iliac crest bone graft (ICBG), either as their sole previous surgical treatment ( $n=6$ ) or as one

of the multiple previous surgical treatments ( $n=1$ ). One patient had no previous surgical intervention.

In all cases, AVN of scaphoid is confirmed by histological examination. In six patients, the initial fracture location was the waist and the other two were proximal. The average prolonged nonunion time of patients was 6.5 years (range, 3–10 years). The number of poor prognostic factors and time to union are shown in Table 2. There was no statistical significance between the number of poor prognosis factors and the time to union, but there was a positive correlation ( $r=0.42$ ,  $p=0.24$ ). According to Herbert classification, there were seven cases of type D3 and one case of type D4.

In all cases, no punctate bleeding was observed from the sclerotic proximal pole during surgery. The fragments and grafts were secured with 3.0-mm cannulated headless compression screws (six cases), or additional K-wires (two cases). All patients achieved union and the average time of union was 4.38 months (range, 3–6 months). Also, all patients with union achieved correction and maintenance of both scapholunate angle and carpal height index. At last follow-up, the wrist ROM was an average of  $43.7^\circ$  extension (range,  $30^\circ$ – $55^\circ$ ;  $p=0.213$ ) and  $50^\circ$  flexion (range,  $40^\circ$ – $60^\circ$ ;  $p=0.567$ ), with a slight improvement compared to preoperatively (average,  $40.0^\circ$  extension and  $41.5^\circ$  flexion) with no significant difference. Forearm rotation and finger ROM were unaffected. The VAS pain scores significantly improved from 5.1 preoperatively to 3.3 postoperatively ( $p=0.041$ ).

**Table 1.** Summary of our results in eight cases

Patient No.	Age (yr) /sex	Affected side	Occupation	Smoking	Mode of injury	Location of initial fracture	Duration after trauma (yr)	Herbert classification	Duration after previous surgery (mo)	Previous surgery	Signs of AVN	Fixation method	Follow-up (mo)	Time to union (mo)
1	44/M	Right	Laborer	Yes	Slip down	Waist	10	D4	NA	NA	Present	HCS	12	3
2	26/M	Right	Student	No	Punching	Waist	5	D3	13	OR/IF with BG	Present	HCS	18	6
3	64/F	Right	Housewife	No	Slip down	Waist	10	D3	8	OR/IF with BG	Present	HCS with additional K-wire	24	3
4	53/M	Left	Farmer	Yes	Slip down	Waist	7	D3	21	OR/IF with BG	Present	HCS	16	4
5	49/M	Right	Laborer	Yes	Slip down	Proximal	5	D3	58, 42	OR/IF, OR/IF with BG	Present	HCS with additional K-wire	14	6
6	51/M	Left	Laborer	Yes	Slip down	Waist	7	D3	36	OR/IF with BG	Present	HCS	14	5
7	56/F	Right	Housewife	No	Slip down	Proximal	3	D3	24	OR/IF	Present	HCS	16	4
8	57/F	Right	Housewife	No	Slip down	Waist	5	D3	13	OR/IF with BG	Present	HCS	32	4

AVN, avascular necrosis; M, male; F, female; NA, not applicable; HCS, headless compression screw; OR, open reduction; IF, internal fixation; BG, bone graft; K-wire, Kirschner wire.

MMWS averaged 77.1 (range, 57–85;  $p=0.820$ ). Of the eight patients, seven were classified as having an excellent or good result and one, average. There was a statistically significant improvement in the average DASH score at the final follow-up (13.2; range, 2.7–28.9;  $p=0.049$ ). Scapholunate relationships in the reconstructed wrists remained almost unchanged, with average scapholunate angles of 49.7° before surgery and 47.0° ( $p=0.198$ ) at the latest follow-up (Table 3). There were no perioperative complications except for three patients with transient knee pain for 1 month in the donor site.

## DISCUSSION

In the current study, the free MFC VBG for the treatment of scaphoid AVN showed promising results in terms of clinical and radiographic results with a low incidence of donor site morbidity.

The well-known poor prognostic factors in scaphoid nonunion are proximal pole nonunion, chronicity, unstable fixation, and AVN [4,9]. Jones et al. [16] analyzed the prognostic factors that may influence the outcome of scaphoid nonunion and determined AVN and previous surgery for nonunion as poor prognostic factors. Another study reported that outcomes are less favorable when nonunion is older than 5 years and in the presence of advanced degenerative changes [4]. The most important factors are known to be the site of pseudoarthrosis and the viability of the proximal pole due to the particularities of dual blood supply. Therefore, if there is suspected impaired blood supply, surgeons are more likely to choose the VBG [2,17].

In many studies, the use of the free MFC VBG demonstrated good results in the treatment of the scaphoid nonunion with poor prognostic factors. Doi et al. [18] reported that the free MFC cortico-periosteal flap has been used as an anterior inlay graft, and achieving union 12 weeks after surgery in 100% of 10 patients with the scaphoid nonunion. Chaudhry et al. [4] found that the union rate after MFC VBG compares favorably with other techniques for a difficult subset of patients with one or more poor prognostic factors in scaphoid nonunion. Jones et al. [16] reported that 40% of scaphoid nonunions treated with the distal radial pedicle graft healed at a median of 19 weeks, and 100% of scaphoid nonunions treated with the free MFC graft healed at a median of 13 weeks. For nonunion treated with the MFC grafts, the union rate was significantly higher and the median duration of healing was significantly shorter. Aibinder et al. [19] compared the three treatment methods of the scaphoid nonunion; ICBG, 1, 2-intercompartmental su-

**Table 2.** Poor prognosis factor in patients and time to union

Patient No.	Proximal pole fracture	Delay time ( $\geq 5$ yr)	Previous nonunion surgery	Histological confirmation of AVN	Poor prognosis factor (n)	Time to union (mo)
1	No	Yes	No	Yes	2	3
2	No	Yes	Yes	Yes	3	6
3	No	Yes	Yes	Yes	3	3
4	No	Yes	Yes	Yes	3	4
5	Yes	Yes	Yes (2)	Yes	4	6
6	No	Yes	Yes	Yes	3	5
7	Yes	No	Yes	Yes	3	4
8	No	Yes	Yes	Yes	3	4

AVN, avascular necrosis.

**Table 3.** Clinical and radiographic outcomes

Variable	Preoperative	Postoperative	p-value
Range of motion ( $^{\circ}$ )			
Flexion	41.5 $\pm$ 8.3	50.0 $\pm$ 11.7	0.567
Extension	40.0 $\pm$ 7.8	43.7 $\pm$ 12.3	0.248
Radial deviation	15.8 $\pm$ 2.1	17.4 $\pm$ 2.3	0.173
Ulnar deviation	19.8 $\pm$ 3.1	22.3 $\pm$ 2.0	0.095
VAS score	5.1 $\pm$ 2.3	3.3 $\pm$ 1.3	0.041
DASH score	52.7 $\pm$ 15.5	13.2 $\pm$ 10.4	0.049
MMWS	45.7 $\pm$ 10.3	77.1 $\pm$ 28.9	0.820
Scapholunate angle ( $^{\circ}$ )	49.7 $\pm$ 3.0	47.0 $\pm$ 1.7	0.198
Carpal height index	0.511 $\pm$ 0.11	0.503 $\pm$ 0.07	0.257

Values are presented as mean  $\pm$  standard deviation.

VAS, visual analogue scale; DASH, the Disabilities of the Arm, Shoulder and Hand questionnaire; MMWS, the modified Mayo wrist score.

preretinacular artery (1, 2-ICSRA), and MFC bone grafts. They found that union rates and mean time to the union were 71% and 19 weeks for the ICBG group, 79% and 26 weeks for the 1, 2-ICSRA group, and 89% and 16 weeks for the MFC group. These findings demonstrate the need for careful patient selection and superiority of MFC VBG, especially in the case of complicated scaphoid nonunions such as AVN, carpal collapse, and previous surgeries. MFC VBG can provide not only structural support but also a rich blood supply to promote bone union and restore structural integrity. This method has the advantage in that large grafts can easily be obtained and less risk of possible torsion to vascular pedicle. Furthermore, it has elasticity and readily conforms to the small tubular bone [6,10,17].

We found similar results in the union rate and the ROM when compared with other studies. Besides, our candidates who underwent MFC VBG for treatment of scaphoid nonunion were able to work with no problems in daily life and were satisfied with their wrist function. However, we were unable to observe the statistically significant differences in some clinical and radiographic results between preoperative and

postoperative values. This may be due to the degree of relatively similar values among study participants and the relatively small number of patients enrolled in this study.

In our study, there were four cases with transient knee pain for a month and self-limited. Since then, there were no more donor site problems. Although MFC VBG has complications such as donor site pain, seroma, and saphenous nerve paresthesia, these were substantially time-limited and overall knee function and gait pattern were barely impaired. Therefore, donor site morbidity can be considered to be a minor issue in the decision-making but need to be cautious. Additionally, these procedures are technically demanding and require attention as there may be anatomical variations in the blood vessels. The extended surgical time and extensive dissection are also important weakness of this surgery.

This study has several limitations. First, it has a retrospective cohort, short-term follow-up, and relatively small sample size. Second, we have selected a similar rehabilitation protocol for all patients regardless of the extent of the AVN size. Numerous rehabilitation protocols have been proposed, but the duration and extent of postoperative immobilization remain controversial. Moreover, we cannot assure patients' compliance with the postoperative rehabilitation protocol.

## CONCLUSION

The free MFC VBG for the treatment of the scaphoid nonunion showed good results with a low incidence of donor site morbidity. This procedure has become a popular technique due to its reliable anatomy, ease of dissection, and other advantages. Therefore, it could accomplish both the structural integrity and the vascularity with a high union rate. Therefore, it could help surgeons manage the scaphoid nonunion associated with poor prognostic factors such as AVN, carpal collapse, prolonged nonunion, and failed prior scaphoid nonunion surgery. Al-

though the results are encouraging so far, a further longer-term study is needed.

## CONFLICTS OF INTEREST

The authors have nothing to disclose.

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## 불량한 예후 인자를 가진 주상골 불유합의 치료에서 내측 대퇴 과두 혈관화 골 이식술의 효용성

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**목적:** 저자들은 불량한 예후인자를 가진 주상골 불유합에 대해 시행한 원위 대퇴골 내과 유리 혈관화 골이식술의 임상적 결과를 보고하고자 한다.

**방법:** 2016년 1월에서 2019년 7월 사이 무혈관 괴사 또는 장기간의 주상골 불유합 환자 8명을 수술했다. 최소 1년 후의 마지막 추사에서 굴곡, 확장, 척골 및 요골 편위 측면에서 손목 움직임, 시각 통증 척도, Mayo 손목 점수, Disabilities of the Arm, Shoulder and Hand (DASH) 점수, 주상월상 각도, 수근골 높이 지수가 측정되었다.

**결과:** 유합을 얻은 8명의 환자에서 주상월상 각도 및 수근골 높이 지수가 교정 및 유지됨을 확인하였고, 시각 통증 점수는 수술 전후 5.1에서 3.3으로 향상되었다. 최종 추적 시 평균 DASH 점수도 통계적으로 유의미하게 개선되었다. 수술 후 손목의 주상월상 관계는 거의 변하지 않았으며, 평균 주상월상 각도는 수술 전 49.7°, 수술 후 가장 최근 추적 시에는 47.0°였다. 불량한 예후 인자의 수와 유합 시간 사이에는 통계적 유의성이 없었으나 양의 상관 관계가 있었다.

**결론:** 무혈성 괴사, 손목 관절 붕괴(외상 후 관절염), 지연된 불유합, 이전의 수술 실패와 같은 불량한 예후 인자를 가진 주상골 불유합의 치료에 원위 대퇴골 내과 유리 혈관화 골이식술이 도움이 될 수 있다.

**색인단어:** 무혈성 괴사, 주상골 불유합, 내측 대퇴 과두 혈관화 골이식술

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