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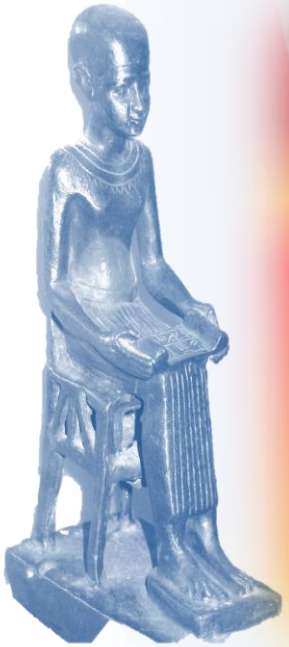

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Original Article

Evaluation of Percutaneous Screw Fixation of Delayed Union Scaphoid Fractures Augmented with Bone Marrow Injection

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Abstract

Background: The conventional approach for treating scaphoid nonunion involves an open surgical technique to correct deformities, perform bone grafting, and achieve stable internal fixation. Many researchers have recommended percutaneous screw fixation as a treatment for minimally displaced acute scaphoid fractures, and it is now being utilized for displaced scaphoid fractures as well. This study aimed to assess the outcomes of percutaneous headless compression screw fixation combined with bone marrow injection in scaphoid delayed union fractures, facilitating early wrist mobilization to promote a quicker return to activities of daily living [ADL].

Patients and methods: This prospective interventional single arm study included twenty patients with delayed scaphoid fractures who were operated with Dorsal percutaneous screw fixation augmented with bone marrow injection and were assessed clinically and radiologically over 6 months after surgery. The primary outcomes of the study included, time from fracture till operation, pain evaluation which was assessed using the visual analogue scale [VAS], Range of motion, Hand grip, Union rate, and Union time.

Results: In terms of pain assessment, the median VAS significantly decreased from 5 [5 – 6] at baseline, indicating moderate pain, to 0 [0] postoperatively, indicating no pain [P = 0.001]. Range of motion [ROM] was initially limited in all patients, but significantly improved to being limited in only 20% at 6 months postoperatively [P = 0.001]. Hand grip strength improved from weak preoperatively to excellent in 80% of patients at 6 months [P = 0.001]. The study also demonstrated an 80% union rate within a median time of 5.5 months.

Conclusion: The use of bone marrow is considered a simple and minimally invasive technique. There was a significant improvement in pain levels during the follow-up period. There was significant improvement in hand grip evaluation over the course of the follow-up period

Keywords: Percutaneous Screw Fixation; Delayed Union Scaphoid Fractures; Bone marrow.

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INTRODUCTION

Scaphoid fractures are the most frequently occurring carpal bone fractures, comprising approximately 60% of all such injuries. Tenderness in the anatomical snuffbox, scaphoid tubercle, and longitudinal compression of the first metacarpi are findings helpful in the diagnosis of a patient with a scaphoid fracture [1].

Early diagnosis of scaphoid fractures is important as delay in diagnosis can lead to complications such as nonunion, avascular necrosis, carpal collapse, and subsequently, a predictable pattern of arthrosis [2].

Conventional radiographs should be the first-choice method in patients with post-traumatic pain on the radial side of the wrist. **Gilbert *et al*.** suggested posterio-anterior [PA], lateral, ulnar-deviated PA and semi-prone oblique [writing position] radiographs [3]. First, the diagnosis can be supported by CT and MRI after radiography [4].

The most widely used classification system in clinical routine is Herbert classification, followed by Rousse and MAYO classifications[5].

Approximately 5-20% of scaphoid fractures cannot be healed with non-surgical treatment [6]. Patients without signs of union despite 6-month follow-up are considered non-union [7]. Surgical treatment is recommended in the majority of unstable scaphoid back fractures and proximal pole fractures with a displacement of more than one millimeter. There are different surgical techniques for its treatment [8].

The conventional treatment for scaphoid nonunion involves an open surgical approach, which includes deformity correction, bone grafting, and rigid internal fixation [9]. Many researchers have endorsed percutaneous screw fixation as an effective method for managing minimally displaced acute scaphoid fractures, and it is now being utilized for displaced fractures as well [10].

If a scaphoid fracture is overlooked or misdiagnosed, it can result in nonunion, eventually leading to radiographic and symptomatic osteoarthritis of the wrist. This progression can cause significant morbidity and lifelong disability, particularly in manual laborers, for whom wrist mobility and hand grip strength are essential [11]. Therefore, this study aims to assess the outcomes of percutaneous headless compression screw fixation combined with bone marrow injection in scaphoid delayed union fractures, enabling early wrist mobilization and facilitating a quicker return to activities of daily living [ADL].

PATIENTS AND METHODS

This prospective interventional single arm study included twenty patients with delayed scaphoid fractures who were operated with Dorsal percutaneous screw fixation augmented with bone marrow injection at Al-Azhar University Hospital in Damietta and were assessed clinically and radiologically over 6 months after surgery. The Institutional Review Board Committee, Damietta Faculty of Medicine, Al-Azhar University approved the study protocol. Informed consents were obtained from each chosen patient pre-operative. We followed the Helsinki declaration principals in this study.

The inclusion criteria were: Patients aged 15–50 years; Patients with delayed-union scaphoid fracture with intact cartilaginous envelope according to Herbert classification type; No cyst or sclerosis, and no avascular necrosis.

The exclusion criteria were: Patients with displaced or comminuted fractures; Fractures of the scaphoid tuberosity; Trans-scaphoid perilunate dislocation, or cases of scaphoid fractures associated with other injuries around the wrist; Avascular necrosis; Patients with delayed scaphoid fracture without intact cartilaginous envelope

Data collection:

Complete medical history taking, and general examination were done for every patent at the time of recruitment. Local examination was also done including the deformity, swelling, tenderness, soft tissue compromise or open injuries, and the neurovascular status of the limb. Routine preoperative laboratory investigation was done. To confirm the diagnosis radiological examination was done including X-ray [anteroposterior, lateral, and scaphoid views], and CT. The primary outcomes of the study included, time from fracture till operation, pain evaluation which was assessed using the visual analogue scale [VAS], Range of motion, Hand grip, Union rate, and Union time.

Surgical technique:

We performed all cases through volar approach. To begin with, the patient was placed on the operating table, either under general or regional anesthesia, and positioned supine. The volar scaphotrapeziod joint was carefully located. To reduce the displaced fractures, fluoroscopy guided the wrist into hyperextension and ulnar deviation, while traction was applied to the thumb to help with any necessary adjustments. The hyperextension allowed the trapezium to move behind the guide wire insertion point at the scaphoid tubercle, and ulnar deviation helped shift the scaphoid away from the radial styloid process.

Next, a guide wire was introduced free-hand under fluoroscopy, directed into the central axis of the distal scaphoid. We confirmed its position through multiple viewings. The wire crossed the fracture site and was advanced to the center of the proximal pole, stopping just at the far cortex.

Following that, a transverse 5 mm skin incision was made around where the guide wire entered, and blunt dissection was carried out down to the distal pole of the scaphoid. The length was measured using either a depth gauge or a wire of the same length to check for differences. A 4 mm screw, slightly shorter than the measured length, was selected to ensure it would be properly embedded in the distal cortex without impacting the proximal cortex. The wire was then advanced further across the proximal pole to maintain its position during the reaming process.

Next, a cannulated drill was inserted around the wire and advanced across the fracture site, stopping just short of the far cortex. Bone marrow aspirated from the iliac bone was injected into the fracture site through the drilling tunnel [Figure 1]. Finally, a self-tapped Herbert screw was inserted free-hand, and the compression at the fracture site was confirmed. The distal end of the screw was placed beneath the surface

Post-operative care: All patients received intravenous antibiotics & analgesia. Patients were discharged after remaining a febrile for 48 hrs. and after they can tolerate normal diet and exhibited a decrease in the white blood cell count to the normal level. Postoperative complications were recorded including postoperative fever and wound infection. The splint was removed about 2–3 weeks postoperatively. Early active range of motion was started with restriction of lifting or working with hand for 3 weeks. Follow-up was done at 1, 3, and 6 months postoperatively

Statistical analysis:

Statistical analysis was performed using SPSS statistical software, version 25 [IBM, Chicago, Illinois, USA]. The normality of the data was tested by the Shapiro test. Qualitative data were presented as numbers and percentages, while quantitative data were presented as Median and inter quartile range [IQR] as it were not normally distributed. Paired continuous data were analyzed by Friedman test, and Wilcoxon test. Paired qualitative data were analyzed by Cochran q test, and McNamar test. Comparison between two independent variables of our continuous and categorical data was done by Mann Whitney U test, and Fisher exact test respectively. As a result, the p-value will be considered significant at the level of <0.05.

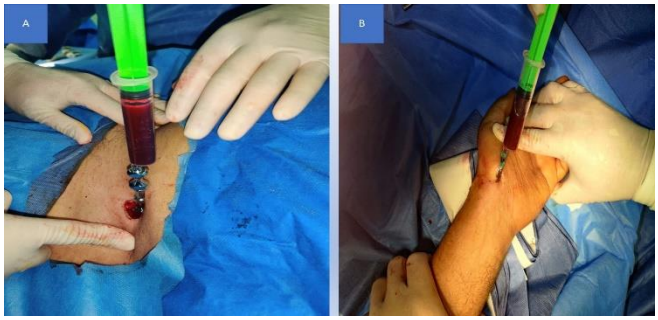

Figure [1]: A] Bone marrow aspiration. B] Bone marrow injection**.**

RESULTS

A total number of 20 patients were included in this study. The median [IQR] age of the patients was 34 [27 – 44] years. 80% of the patients were male and 20% were females [Table 1].

As regards the patients' comorbidities, 20% of the patients were diabetic. According to the type of fractured bone, 16 patients [80%] hade fracture waist, and 4 patients [20%] had fracture distal pole. The median time from fracture till the operation was 10 [10 – 11] weeks [Table 2].

As regards the pain assessment by VAS, the median VAS was significantly reduced from 5 [5 – 6] which is moderate pain at the baseline to 0 [0] postoperatively which is no pain [P = 0.001] [Table 3].

According to the ROM, it was limited in all patients preoperatively, which was significantly reduced to be limited in 20% of the patients only at 6 months postoperatively [P =0.001] [Table 4]. In terms of the hand grip, it was weak in all patients preoperatively, which was improved to be excellent in 80% of the patients at 6 months postoperatively [P=0.001] [Table 5]. According to the union rate, our study showed a union rate of 80% in a median time of 5.5 [5 – 6] months [Table 6].

A comparison between the union and nonunion cases was done, and we found that, the median age of the union cases was significantly younger than that of the non-union cases [P= 0.001]. Also, all of the union cases were females [P = 0.001] [Table 7].

Table [1]: Demographic data of the studied patients

Variables	Median [IQR] / N [%]
Age [Years]	
Median [IQR]	34 [27 – 44]
Range	[20 – 44]
Gender	
Male	16 [80%]
Female	4 [20%]

Table [2]: Baseline clinical data of the studied patients

Variables	Median [IQR] / N [%]
Comorbidities	
DM	4 [20%]
None	16 [80%]
Type of fractured bone	
Waist	16 [80%]
Distal Pole	4 [20%]
Time from fracture till operation [Weeks]	
Median [IQR]	10 [10 – 11]
Range	[10 – 12]

Table [3]: Pain assessment of the studied patients

VAS	Preoperative	Post 1 m	Post 6 m	P value	P value
Median [IQR]	5 [5 – 6]	1 [1 – 1]	0 [0]	0.001 [a] *	P1=0.001[b]*; P2= 0.001[b]*; P3= 0.001[b]*
VAS Categories					
No	0 [0%]	0 [0%]	16[80%]	0.001 [c]	P1= 0.9 [d]; P2=0.001[d] *; P3= 0.001 [d] *
Mild	0 [0%]	20[100%]	4 [20%]		
Moderate	20[100%]	0 [0%]	0 [0%]		

a: Friedman test. b: Wilcoxon test. c: Cochran q test. d: McNamar test. P1: preop vs post 1 month. P2: preop vs post 6 months. P3: post 1 month vs post 6 months. VAS: Visual Analogue Scale.

Table [4]: Range of motion assessment of the studied patients

ROM	Preoperative	Post 1 month	Post 6 months	P value [a]	P value [b]
Limited	20 [100%]	4 [20%]	4 [20%]	0.001*	P1= 0.001 *; P2= 0.001 *; P3= 0.9
Full	0 [0%]	16 [80%]	16 [80%]		

a: Cochran q test. b: McNamar test. P1: preop vs post 1 month. P2: preop vs post 6 months. P3: post 1-month vs post 6 months.

Table [5]: Hand grip assessment of the studied patients

Hand grip	Preoperative	Post 1 month	Post 6 months	P value [a]	P value [b]
Weak	20 [100%]	4 [20%]	0 [0%]	0.001*	P1= 0.001 *; P2= 0.001 *; P3= 0.001*
Good	0 [0%]	16 [80%]	4 [20%]		
Excellent	0 [0%]	0 [0%]	16 [80%]		

a: Cochran q test. b: McNamar test. P1: preoperative vs postoperative 1 month. P2: preoperative vs postoperative 6 months. P3: postoperative 1 month vs postoperative 6 months.

Table [6]: Success rate of the studied patients based on radiological assessment.

Variables	Median [IQR] / N [%]
Union rate	
Union [Success rate]	16 [80%]
Nonunion [Failure rate]	4 [20%]
Union time [Months]	
Median [IQR]	5.5 [5 – 6]
Range	[5 – 6]

Table [7]: Comparison between the Union and nonunion cases regarding the different study variables.

Variables	Union [N= 16]	Nonunion [N=4]	P value
Age [Years]			
Median [IQR]	30.5 [21.5 – 41.5]	44 [0]	0.01[a] *
Gender			
Male	16 [100%]	0 [0%]	0.001[b]*
Female	0 [0%]	4 [100%]	
Comorbidities			
DM	4 [25%]	0 [0%]	0.5[b]
None	12 [75%]	4 [100%]	
Type of fractured bone			
Waist	12 [75%]	4 [100%]	0.5[b]
Distal Pole	4 [25%]	0 [0%]	
Time from fracture till operation [Weeks]			
Median [IQR]	10.5 [10 – 11.5]	10 [0]	0.08[a]

a: Mann Whitney U test. b: Fisher exact test.

DISCUSSION

This study assesses the efficacy of percutaneous headless compression screw fixation with bone marrow injection in treating scaphoid delayed union fractures, aiming to facilitate wrist movement and expedite recovery of activities of daily living [ADL]. Our study showed that the median age was 34 years. 80% were male and 20% were female.

In a study by **Sahu *et al.*** [12], a total of 93 patients with long bone delayed union and nonunion [56 delayed unions and 37 non-unions] were enrolled from the Emergency and Outpatient Departments and underwent treatment with percutaneous autologous bone marrow injections. The clinical outcomes of the study were assessed based on union criteria, with all patients being monitored for a follow-up period of 24 months. Among the participants, 72.04% [67 out of 93] were male, while 27.95% [26 out of 93] were female. The patients' ages ranged from 16 to 86 years.

Tabl [13] sought to assess the impact of bone marrow injection on bone healing in scaphoid fractures with delayed presentation, utilizing percutaneous fixation with a Herbert screw. Mean age was 30±2.2, 75% were male and 25% were female.

Our study illustrated that median time from fracture till operation was 10 weeks. 80% had waist and 20% had distal pole. In the study by **Sahu *et al.*** [12], 11 cases of long bone fractures failed to unite due to the patients' heavy smoking habits. Tibial fractures accounted for 20.43% of the cases included in the study. Previous research has highlighted the relatively high incidence of delayed union and nonunion in tibial fractures compared to other long bone fractures. This increased prevalence is primarily attributed to the higher occurrence of open tibial fractures, given the bone's subcutaneous anatomical position, as well as its unique vascularization, both of which contribute to delayed healing. **Tabl** [13] showed that time from fracture till operation was 12±2.

Our study demonstrated that there was significant improvement in pain through period of follow up. **Tabl** [13] showed that there was great significance in group A according to postoperative VAS score in comparison with group B.

In a study by **Tabl and Kandel** [14], a total of 20 patients [22 scaphoid fractures] with delayed union of the scaphoid underwent percutaneous headless screw fixation combined with bone marrow injection from the iliac bone. The inclusion criteria for this study included scaphoid delayed-union fractures with an intact cartilaginous envelope, the absence of sclerosis, and no signs of avascular necrosis. At the final follow-up, the average Visual Analog Scale [VAS] score was 0.05. The mean wrist range of motion measurements were 85° flexion, 76.5° extension, 18.5° radial tilt, and 42.5° ulnar tilt.

Our study revealed that there was significant improvement in ROM through period of follow up. Our study showed that there was significant improvement in Hand grip assessment through period of follow up. **Sahu *et al.*** [12] reported excellent outcomes in 68.81% [64/93] of cases, good outcomes in 19.35% [18/93], and poor outcomes in 11.82% [11/93]. In terms of subjective overall assessment, 68.81% [64/93] of patients were fully satisfied, while 19.35% [18/93] expressed satisfaction with their treatment outcomes. The authors attributed the high success rate [88.12% union] to careful case selection, focusing on patients whose delayed union was primarily due to biological factors, while excluding those with mechanical causes of delayed or nonunion, which could have negatively impacted the results.

Tabl [13] showed that there was great significance in group A according to postoperative hand grip in comparison with group B. Tabl and Kandel [14] showed that Grip strength regained at an average of 95% [85–100%] in comparison with the other side.

Our study demonstrated that 80% had union while 20% had nonunion. Union time [Months] was 5.5 months. **Sahu *et al.*** [12] reported that all fractures, including delayed union and nonunion, achieved union within 12 weeks on average, with a minimum healing time of 8 weeks and a maximum of 16 weeks. The success rate of bone marrow injection varied by fracture site, with femoral fractures uniting in 85.71% of cases, tibial fractures in 89.47%, humeral fractures in 88.23%, radial fractures in 90%, and ulnar fractures in 87.5%. Additionally, the study found that 100% of delayed union cases healed, while hypertrophic nonunion achieved union in 75% of cases, and atrophic nonunion in 61.53% of cases.

Tabl [13] showed that there was great significance in group A according to postoperative union rate in comparison with group B. Two patients in group A had mild discomfort at their iliac crest donor site, which resolved within a few days without any medications. One patient in group B did not get any signs of progressive union till 13 weeks, so open surgery and graft were done and union achieved 3 months later.

Several studies with different revascularization enhancement methods for delayed scaphoid fractures were done. A study by **Tomasz *et al.*** [15] on seven patients with delayed scaphoid fractures treated by bone marrow aspirate concentrate injection and plaster splint for 8 weeks, they achieved union rate about 12 weeks with mild decrease in wrist range of motion till 4 months' post cast removal.

Another study by **Mekaouche *et al.*** [16] on 12 patients with delayed scaphoid fractures using commercially available device such as the two-step centrifugation Arthrex ACP system with percutaneous screw fixation, they achieved union rate [7–10 weeks] with good results but with expensive cost of commercial platelet-rich plasma. **Taskin *et al.*** [17] evaluated 33 consecutive scaphoid-delayed unions or nonunion treated by dorsal percutaneous fixation only. Union achieved on average 11 weeks. **Tabl and Kandel** [14] showed that all their patients had satisfactory results. A total of 21 fractures fully united without additional maneuvers, and one fracture proceed to nonunion and need re-surgery with open graft and fixation. This fracture was in patient number 4 with bilateral fracture of the scaphoid 2.5 months ago. He had conservative treatment for 9 weeks in the form of short cast. Dorsal percutaneous fixation with bone marrow injection was done for the both sides. The right side united within 8 weeks, but the left side proceeded to nonunion with screw intra-articular penetration at 6 weeks postoperatively. They explain the cause of failure in union owing to improper compression in fracture site and improper screw length, as they did not use the hook in the first four cases and used manual compression from the thumb against screw insertion. However, after this case, they decided to use the hook to achieve best compression and alignment, and all cases after this modification had no complications.

Our study found that there was significant difference between the Union and nonunion cases regarding age and gender. **Sahu *et al.*** [12] found that the time to union was significantly shorter in female patients compared to males [p = 0.041].

Several studies [18-21] have highlighted the effectiveness of percutaneous bone marrow injection, particularly when combined with a composite graft, in treating simple bone cysts, congenital tibial

pseudoarthrosis, and delayed union in challenging clinical scenarios, such as in cancer patients. **Ma *et al*.** [22] successfully utilized bone marrow injection to enhance fracture healing in various bones, including the tibia, femur, metatarsals, and humerus, even in cases complicated by infection or pathological fractures, yielding similarly favorable outcomes. Regarding complications, no cases of infection or pain were reported at either the donor or injection sites. Bone marrow injection is a minimally invasive, safe technique, as it uses autogenous material, eliminating the risk of disease transmission or immune rejection. Unlike iliac bone grafting, this method avoids additional surgical incisions and donor site morbidity, as the bone marrow is injected percutaneously, preserving the integrity of the fracture site.

The present study is **limited** by its small sample size and the absence of a control group for direct comparison. Consequently, while bone marrow injection shows promise as a bone regeneration enhancement, we acknowledge that without a comparative arm, definitively proving its efficacy over other techniques or natural healing is not possible. Future studies should incorporate a double-armed comparative design to rigorously evaluate the true benefit of bone marrow injection in this context

Conclusion: Bone marrow injection appears to be a simple and minimally invasive technique for augmenting percutaneous screw fixation of delayed union scaphoid fractures. Our study demonstrated significant improvements in pain levels and hand grip strength during the follow-up period. Future double-armed comparative studies are needed to rigorously confirm the efficacy of this technique compared to other treatments or natural healing processes. While our findings are encouraging, they should be interpreted with caution until further comparative evidence is available.

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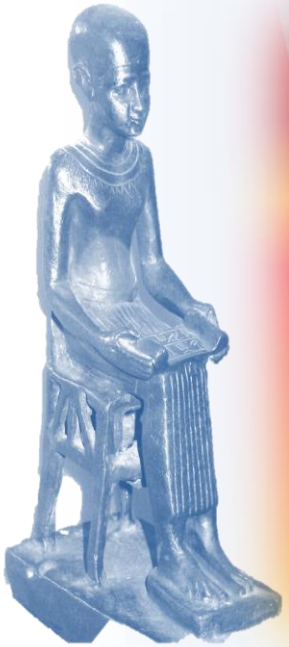

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