



## Functional Outcome of Screw Fixation without Bone Graft for Delayed Union and Non-Union Scaphoid Fracture

Dr. Mohamed Alhassan Osman Hassan <sup>1\*</sup>, Mr. Elhadi Abdelrahim <sup>2</sup>

1. MBBS Omdurman Islamic University 2012
2. MBBS, M.D. (TR&Orth), Consultant Orthopaedic and hand Surgery.

**Corresponding Author: Dr. Mohamed Alhassan Osman Hassan**, MBBS Omdurman Islamic University 2012.

**Copy Right:** © 2022 Dr. Mohamed Alhassan Osman Hassan, This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Received Date: October 14, 2022**

**Published Date: November 01, 2022**

**Abstract**

*Scaphoid fractures are the most common fractures of the carpal bones, Delay in diagnosis and inadequate treatment of acute scaphoid fractures can lead to non-unions, avascular necrosis, carpal collapse and subsequently a predictable pattern of arthrosis, challenging surgeons regarding optimal management.*

*Our study was Multicenter base study to assess the functional outcome of Herbert screw fixation in delayed union and non-union scaphoid fractures without bone graft.*

*This was a descriptive cross-sectional hospital-based study conducted on 35 patients with delayed scaphoid fracture who underwent fixation with Herbert screw without bone graft. In this study patients were evaluated for improvement of pain, grip strength, wrist range of motion and functional status after at least 6 months of operation using mayo wrist score, and analyzed using SPSS.*

*In our study 34 of the 35 (97%) fractures united successfully with no additional procedures. These fractures achieved radiographic union at an average of 4 months. One patient required revision fixation with additional bone graft. The average mayo wrist score at final follow-up was 90 (range 80–100). The mean preoperative flexion improved from 19.85° to 72.85° and the mean preoperative extension improved from 16.42 to 60.57°. None of the patients showed radiographic signs of osteoarthritis, osteonecrosis of the scaphoid, or hardware related complications.*

*In conclusion fixation with Herbert screw without bone graft for delayed union and non-union scaphoid fractures, provides satisfactory results with a high union rate, early return of function and minimal complications. And also concluded that extensive resorption at the fracture site is not an absolute indication for bone grafting, and that percutaneous fixation alone will eventually produce healing of non-united un-displaced fractures of the scaphoid regardless of the size of the gap.*

## Abbreviations

SPSS Statistical package for social science

EDC Education development center

AVN Avascular necrosis

## Introduction

Scaphoid fractures are the most common fractures of the carpal bones, accounting for 70% to 80% of all carpal fractures [1,2] and 11% of all hand fractures [3]. In adults, 70% of all scaphoid fractures involve the waist of the scaphoid, 20% involve the proximal pole, with the remaining 10% involving the distal pole [4]. Young males between 10 and 19 years of age are at highest risk for fracture of the scaphoid [5]. Non-displaced fractures of the distal third of the scaphoid have excellent healing potential, while fractures of the waist and proximal third of the scaphoid have higher rates of non-union [6]. Appropriate and early diagnosis of scaphoid fractures is imperative since delay in diagnosis can lead to complications such as non-union and avascular necrosis [7].

## Problem Statement and Justification

The standard method of treatment for scaphoid non-union is an open approach for deformity correction, bone grafting and rigid internal fixation. The grafts utilized can be non-vascularized, pedicled rotational vascularized bone graft or vascularized bone graft [8]. Screw fixation without bone graft has been advocated for minimally displaced acute scaphoid fractures and was recently reported for displaced scaphoid fractures, A few reports have described the open and percutaneous approaches for treating scaphoid delayed unions and non-unions without bone graft [9,10].

Percutaneous screw fixation without bone graft technique has the advantages of not devascularizing the scaphoid, avoiding division of the carpal ligaments, providing a much more aesthetic scar, not to do second incision for graft, not to expose patient to bone graft complications (surgical site infection and bleeding), short anesthetic time and hospital stay.

Lack of local studies and limited literature reviews regarding outcome of screw fixation in established non-union scaphoid fracture without bone graft is a main cause to conduct this study.

## Research question

What is the Functional outcome of screw fixation without bone graft for delayed union and non-union scaphoid fracture?

## Objectives

- General objective:

To assess the functional outcome of Herbert screw fixation in delayed scaphoid fracture without bone graft.

- Specific objectives:
  1. To evaluate the range of motion of wrist joint pre- and post-operative using Mayo Wrist Score.
  2. To identify common post-operative complications.

## Materials and Methods

### Methodology

#### Study design

- This is a descriptive cross-sectional hospital-based study.

#### Study area and period:

- Dar Alelaj specialized hospital, Elsheikh specialized hospital, Alfoad specialized hospital, Omdurman teaching hospital and Waad specialized hospital, during study period from February 2018 – May 2020.

#### Study population

- All patients those underwent screw fixation without bone graft for delayed and non-union scaphoid fracture in study area during study period.

#### Sample Size

- Total coverage sample
- About 35 cases operated in study area according to surgeon Data.

**Exclusion Criteria**

- Patients with delayed union and non-union scaphoid fracture with significant scaphoid collapse, humpback deformity, dorsal intercalated segment instability deformity, osteonecrosis of the proximal scaphoid fragment, or arthrosis of the wrist.

**Data collection:**

- Data was collected by researcher alone.
- Data was collected using Interviewer -administered questionnaire will be developed into:

Section 1: Personal data.

Section 2: Range of motion in affected Wrist before and after surgery using Mayo Wrist score.

- The researcher examined the patients to assess the range of Wrist motion after surgery and take the pre-operative range of motion values from hospital record.

Section 3: Need for physiotherapy and post-operative complications.

**Data analysis:**

- The study was analyze using statistical package for social science (SPSS), Version 21, Frequency -chi-square set point (p-value < 0.05).

**Ethical consideration**

- Ethical clearance from ethical clearance committee Sudan medical specialization board.
- Approval from EDC.
- Informed written consent from participants was took after purposes and nature of study was explained.
- Participants assure that their data will be confidential.
- Hospital permission was taken from hospital mangers.

## Results

According to demographic data:

- This study conducted in 35 participants, consisted of 32 males (91.4%) and 3 females 8.6% with male to female ratio 11: 1 (figure 1).
- The mean age of the participants when conducting the study is 27.6, with minimum of 17 years and maximum age was 42 years, (table 1).
- The majority of patients has Right dominant hand 28 patients (88.6%) and only 7 patients have left dominant hand (11.5%) (figure 2).
- The majority of the study group 27 patients (77.1%) had right Hand involvement, whereas the remaining Eight patients had involvement of the left Hand (22.9%) and there was no bilateral involvement (figure 3).
- In this study we found that in 28 patients with right dominant hand only 3 patients (8.6%) had left hand scaphoid fracture. In other side patients with left dominant hand: 5 patients (14.3%) had left hand scaphoid fracture (table 2).
- The time between injury and surgery was (3) months in 17 patients (84.5%), (4-6) months in 14 patients (40%) and more than 6 months in 4 patients (11.5%) (figure 4).
- The follow up after surgery was (6 month-9 months) in 23 patients (65.7%), (10-12 months) in 10 patients (28.5%), (13-18 months) in 2 patients (5.8%) (figure 5).
- The study shows that 24 patients (68.6%) had scaphoid waist fracture and only eleven patients (31.4%) presented with scaphoid proximal pole fracture (figure 6).
- According to surgical approach, the study shows that 20 patients (57.14%) were treated with dorsal percutaneous approach, 9 patients (25.71%) with volar percutaneous approach and 6 patients (17.14%) with open volar approach (figure 7).

**According to range of motion, (table 3):**

- The mean preoperative wrist flexion was  $19.86^{\circ}$  with minimum  $5^{\circ}$  and maximum of  $35^{\circ}$  and postoperative wrist flexion mean was  $72.86^{\circ}$  with minimum  $50^{\circ}$  and maximum  $90^{\circ}$  with mean gain of  $53^{\circ}$  in wrist flexion after fixation.

This shows highly statistically significant improvement of wrist flexion with p value  $< 0.01$ .

- The mean preoperative wrist extension was 16.43° with minimum of 5° and maximum of 30° and postoperative wrist extension was 60.57° with minimum of 40° and maximum was 75° with mean gain 44.14 degree in extension post operatively.

This reflects significant improvement of wrist extension with p value < 0.02.

There is no significant deference in postoperative range of motion in deferent age

Groups, gender and whether the affected limb was right or left. (Tables 5-6-7)

- All patients underwent wrist and hand physiotherapy (table 8).

**According to Mayo wrist score, (table 4) and (table 5):**

The mean Mayo wrist scores for the individual elements similarly demonstrated improvement following fixation, with the greatest gains in range of motion, grip strength, decrease in pain intensity, and improvement in functional status.

The mean mayo wrist score for pain intensity was 6.43 and the mean post-operative mayo wrist score for pain intensity was 24.29.

This shows statistically highly significant improvement of mallet score for pain intensity with p value < 0.01.

In our study we found that there is a significant improvement of mayo wrist score for Functional status with p value <0.01, and mean preoperative mayo score was 1.71 and the mean postoperative mayo score is 19.86.

The mean pre-operative mayo wrist score for Range of Motion was 3.14 and the mean post-operative mayo wrist score for Range of Motion is 23.00.

This shows statistically highly significant improvement of mayo wrist score for Range of Motion with p value < 0.01.

The mean pre-operative mayo wrist score for Grip strength (% of normal) was 4.29 and the mean post-operative mayo wrist score for Grip strength (% of normal) is 23.57.

Again, this shows statistically highly significant improvement of mayo wrist score for Grip strength (% of normal) with p value < 0.01.

The study shows greater improvement in total mayo score, from Total Pre-operative mayo wrist score 15.57 to Total Post-operative mayo wrist score 90.7 (table 4).

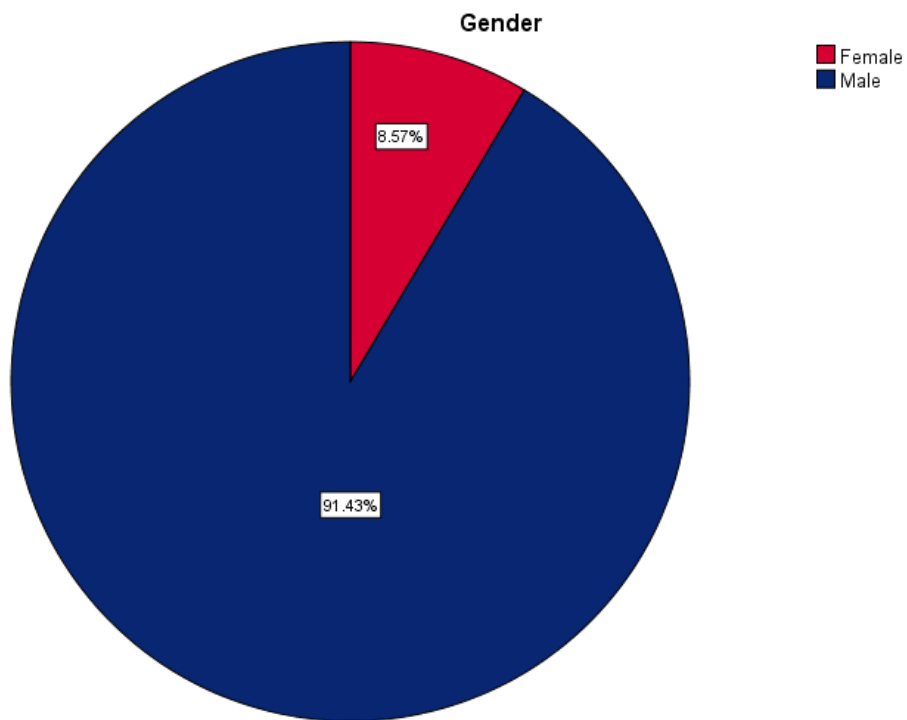


Figure 1: Gender distribution.

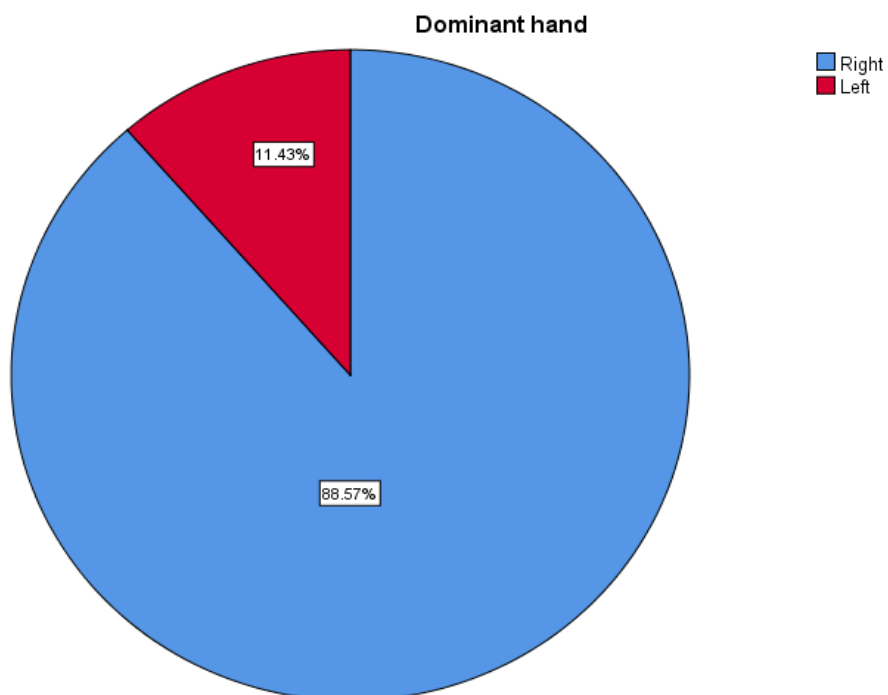
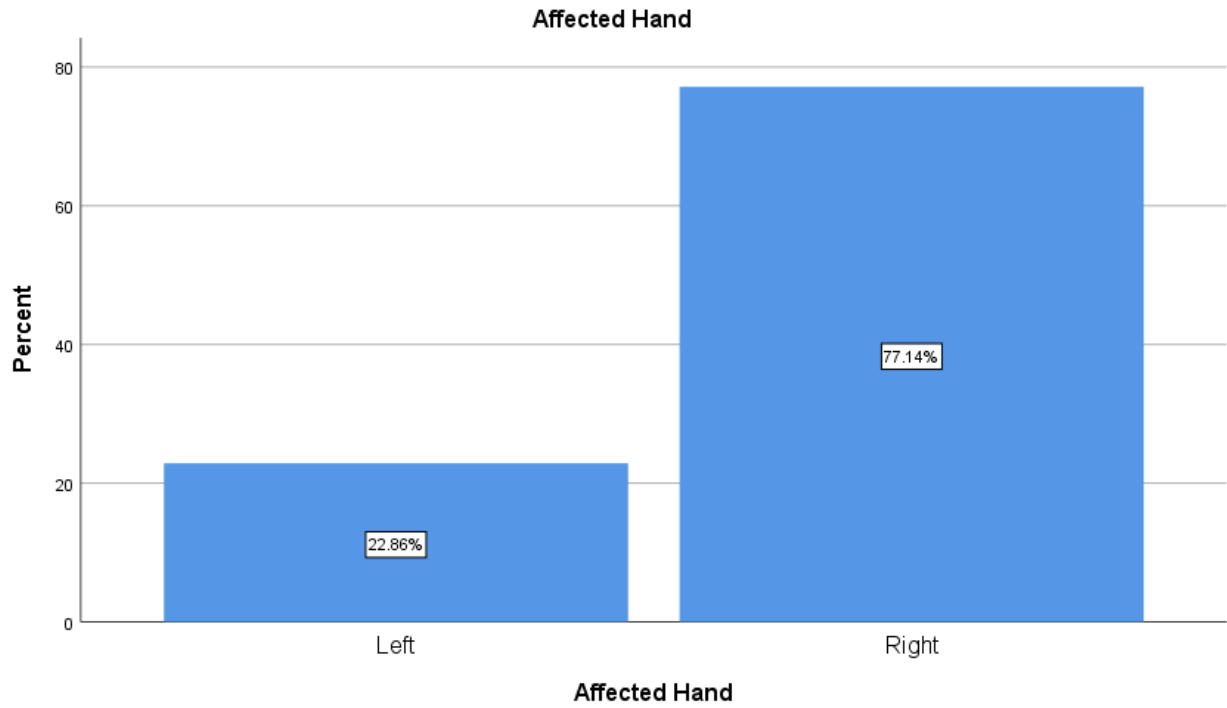
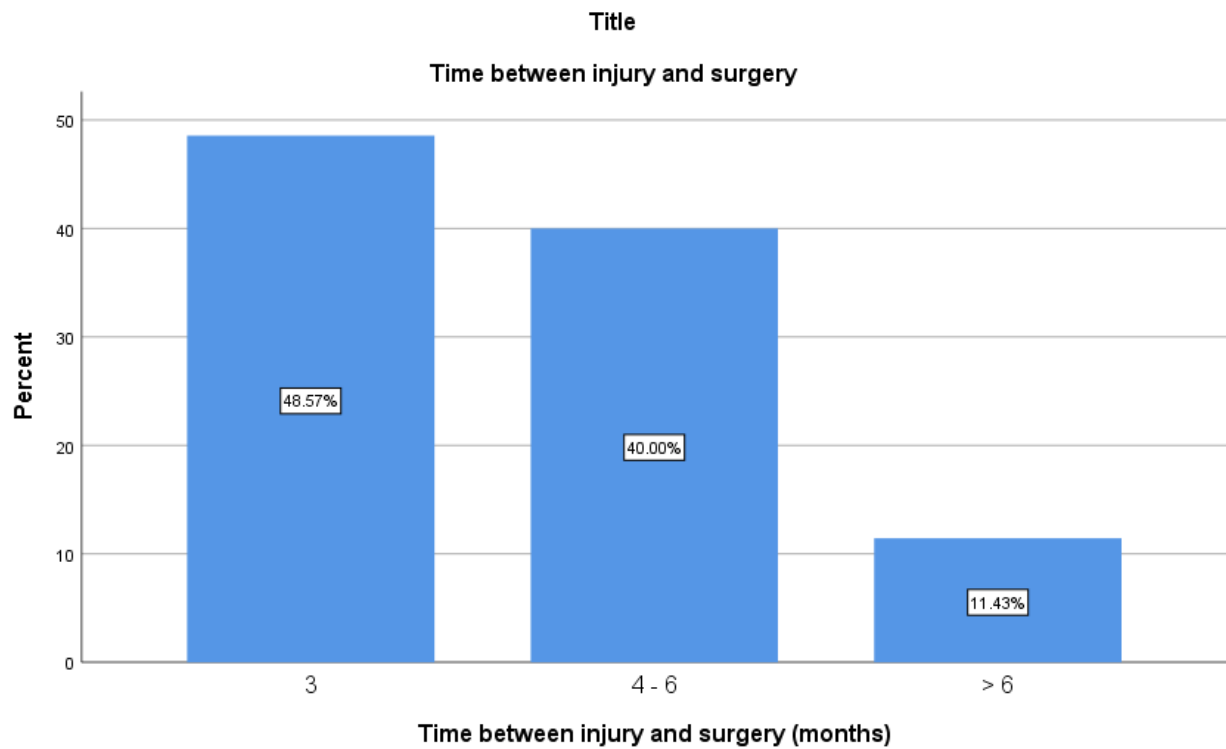


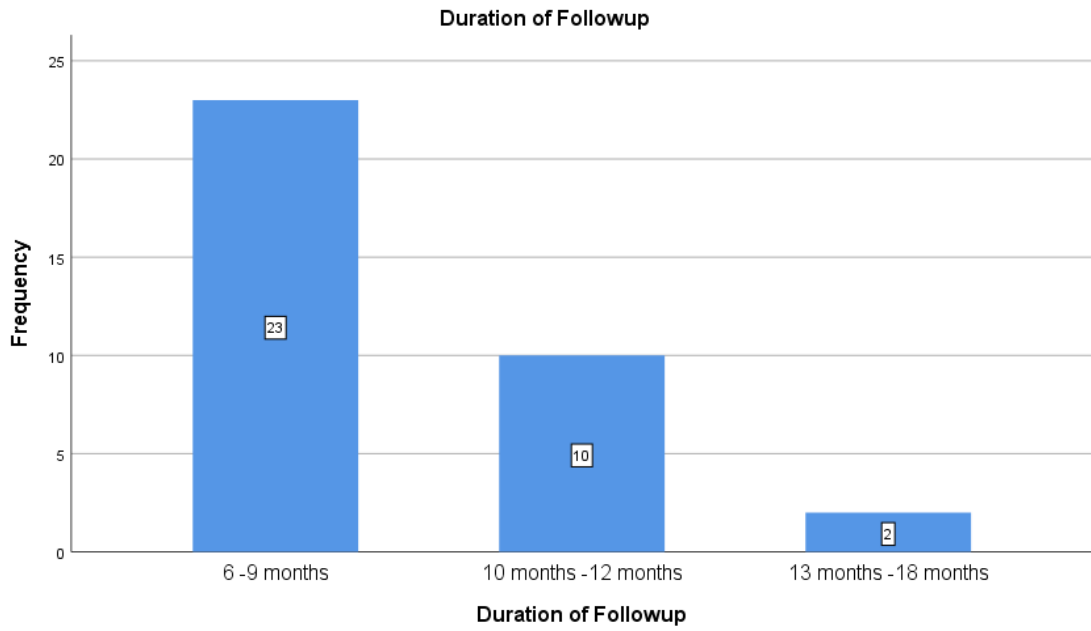
Figure 2: Distribution according to dominant hand



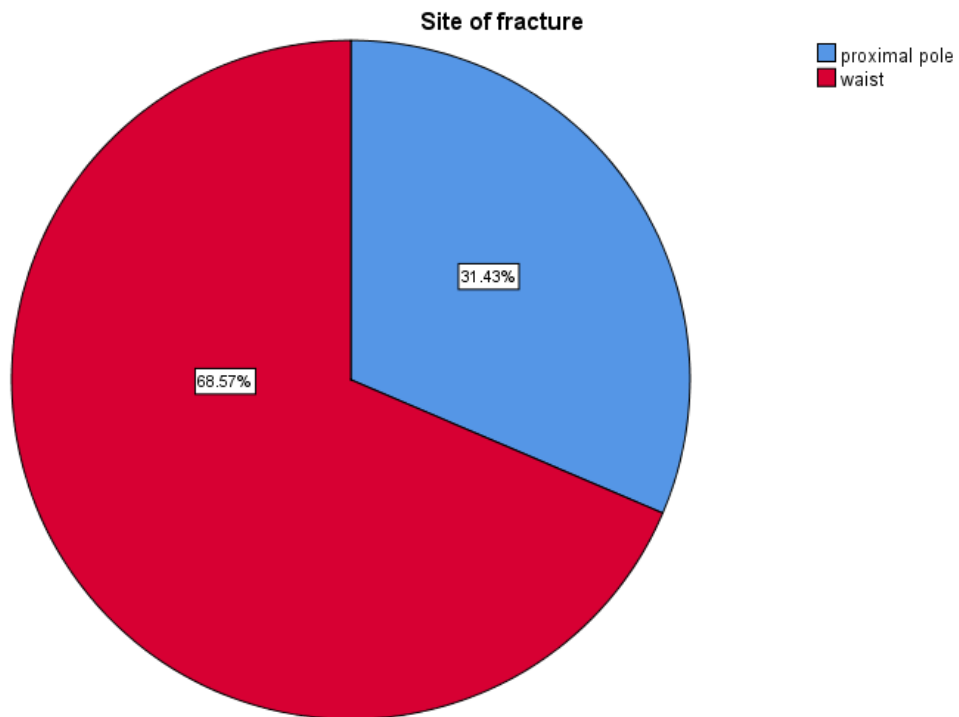
**Figure 3:** distribution according to Affected Hand



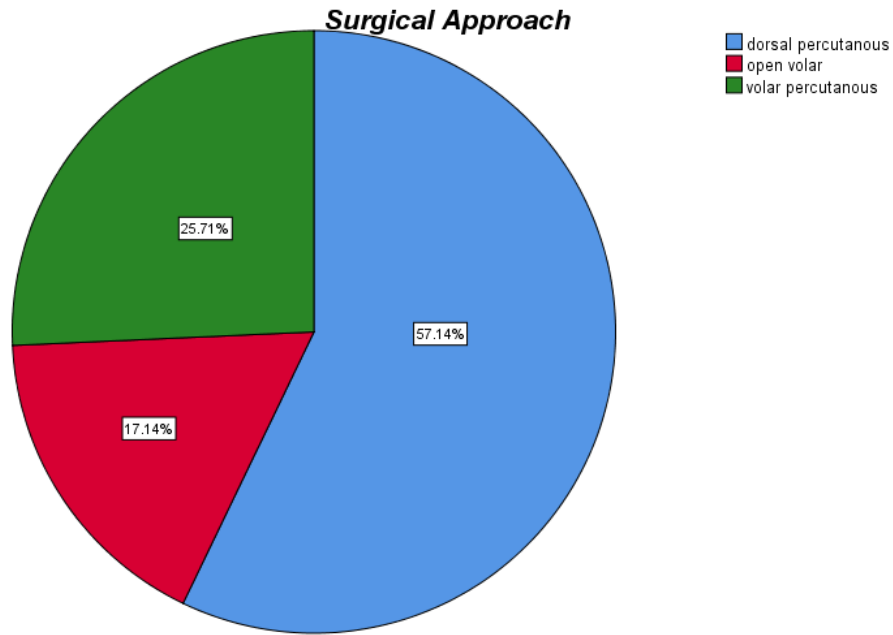
**Figure 4:** distribution according to Time between injury and surgery



**Figure 5:** distribution according to duration of follow up



**Figure 6:** distribution according to Site of Fracture



**Figure 7:** distribution according to Surgical Approach

	N	Minimu m	Maximu m	Mean
Age	35	17	42	27.60

**Table 1:** Distribution according to age

		Affected Hand		Total
		Right	Left	
Dominant Hand	Right	25 89.3%	3 10.7%	28
	Left	2 28.6%	5 71.4	7
Total		27	8	35

**Table 2:** Association between dominant hand and affected hand

	N	Minimum	Maximum	Mean
Pre-operation Flexion	35	5	35	19.86
Pre-operation Extension	35	5	30	16.43
Post-operation Flexion	35	50	90	72.86
Post-operation Extension	35	40	75	60.57

**Table 3:** Distribution according to range of motion

		Pre-operative	Post-operative
<b>Mayo wrist score for pain intensity</b>	No pain	0	30
	Mild occasional	0	5
	Moderate, tolerable	15	0
	Sever to intolerable	20	0
<b>Mayo wrist score for Functional status</b>	Returned to regular employment	0	16
	Restricted employment	3	2
	Able to work, but unemployed	0	17
	Unable to work because of pain	32	0
<b>Mayo wrist score for Range of Motion</b>	Greater than 120 degrees	0	28
	90-120 degrees	0	7
	60-90 degrees	1	0
	30-60 degrees	20	0
	Less than 30 degrees	14	0
<b>Mayo wrist score for Grip strength % of normal</b>	100%	0	30
	75-100%	0	5
	50-75%	8	0
	25-50%	14	0
	0-25%	13	0

**Table 4:** Distribution according to Mayo wrist Score

	Mean
Pre-operative mayo wrist score for pain intensity	6.43
Post-operative mayo wrist score for pain intensity	24.29
Pre-operative mayo wrist score for Functional status	1.71
Post-operative mayo wrist score for Functional status	19.86
Pre-operative mayo wrist score for Range of Motion	3.14
Post-operative mayo wrist score for Range of Motion	23.00
Pre-operative mayo wrist score for Grip strength % of normal	4.29
Post-operative mayo wrist score for Grip strength % of normal	23.57
<b>Total</b> Pre-operative mayo wrist score	15.57
<b>Total</b> Post-operative mayo wrist score	90.7

90-100 = Excellent    80-90 = Good    60-80 = Satisfactory    Below 60 = Poor

**Table 5:** Association between pre- and post-operative Mayo wrist score

Affected Hand		Post-operative mayo wrist score for pain intensity	Post-operative mayo wrist score for Functional status	Post-operative mayo wrist score for Range of Motion	Post-operative mayo wrist score for Grip strength % of normal
<b>Left</b>	Mean	24.38	15.63	23.75	23.75
	N	8	8	8	8
<b>Right</b>	Mean	24.26	21.11	22.78	23.52
	N	27	27	27	27
<b>Total</b>	Mean	24.29	19.86	23.00	23.57
	N	35	35	35	35

**Table 6:** Association between affected limb and post-operative Mayo wrist score

Time between injury and surgery		Post-operative mayo wrist score for pain intensity	Post-operative mayo wrist score for Functional status	Post-operative mayo wrist score for Range of Motion	Post-operative mayo wrist score for Grip strength % of normal
<b>&gt; 6 months</b>	Mean	21.25	23.75	15.00	17.50
	N	4	4	4	4
<b>3 months</b>	Mean	24.71	20.29	24.41	25.00
	N	17	17	17	17
<b>4 – 6 months</b>	Mean	24.64	18.21	23.57	23.57
	N	14	14	14	14
<b>Total</b>	Mean	24.29	19.86	23.00	23.57
	N	35	35	35	35

**Table 7:** Association between Time between injury and surgery and post-operative MAYO score

Need of Physiotherapy		Post-operative mayo wrist score for pain intensity	Post-operative mayo wrist score for Functional status	Post-operative mayo wrist score for Range of Motion	Post-operative mayo wrist score for Grip strength % of normal
<b>Yes</b>	Mean	24.29	19.86	23.00	23.57
		35	35	35	35

**Table 8:** Association between patient need for post-operative physiotherapy and post-operative MAYO score

## Discussion

Non-union of the scaphoid is generally defined as failure of radiographic evidence of union at 6 months after the injury. Anatomically, the complex three-dimensional shape, tenuous blood supply, and 80% cartilage covering of the scaphoid make effective management of non-unions challenging.

Percutaneous fixation of scaphoid fractures with cannulated screws was first performed in 1962 in Germany by Vonr Strelia via a small volar incision [27]. Slade [9] pioneered dorsal percutaneous fixation with a headless cannulated screw using mini fluoroscopy. Percutaneous techniques have resulted in faster recovery time and decreased duration of cast immobilization in acute scaphoid fractures, compared with non-surgical management. Bond et al. [28] in a prospective randomized study compared percutaneous fixation of acute fractures (11 patients) with cast immobilization (14 patients). They demonstrate an earlier time to union (7 weeks vs. 12 weeks) and earlier return to work (8 weeks vs. 15 weeks with casting) with percutaneous fixation. Another prospective randomized trial of 60 patients with acute fractures of the scaphoid showed faster radiologic union (9.2 weeks vs. 13.9 weeks,  $P < 0.001$ ) and a more rapid return of function with percutaneous screw fixation as compared to cast immobilization [29].

Percutaneous screws can be placed either by a volar or dorsal approach. The decision when choosing the approach is generally dependent on the fracture location and surgeon preference. For more proximal fractures a dorsal approach is recommended, with the screw being placed in an antegrade direction. This approach facilitates optimal screw placement in the central part of the proximal pole, ensuring good compression and better stability. Disadvantages are that the wrist must be hyper flexed and thus the guidewire may be inadvertently bent, and extensor tendon injuries can occur [30]. Conversely, for waist and more distal fractures, a volar approach is often preferred with the screw being placed from distal to proximal within the scaphoid [31].

Recent publications report the use of percutaneous techniques in the treatment of delayed and non-unions of the scaphoid. Wozasek and Moser [32] described 25 cases with delayed union and 8 with established non-unions treated with a percutaneous dorsal approach. Bony healing was achieved in 27 cases (81.8%) after a mean postoperative time of 82 months. In another study Ledoux and co-authors [33] reported a 100% union rate and a rapid return to work in 19 patients with acute fractures and 4 with non-unions managed with percutaneous screw fixation. Slade et al. [9] evaluated 15 patients with a fibrous or non-union of the scaphoid treated with arthroscopic examination and dorsal percutaneous fixation with a headless screw without bone graft. Computed tomography scans were performed at approximately 4–6 weeks postoperatively and then repeated every 6 weeks until union was achieved.

All 15 fractures healed with the average time to union of 14 weeks with no complications. They noted that the time to union was substantially less in fractures treated within 6 months of injury (10.8 weeks) compared to those treated later (16 weeks,  $P < 0.02$ ). Recently Kim et al. [10] treated 12 patients with scaphoid waist delayed union using the volar percutaneous approach. All fractures united uneventfully with a mean DASH score of 9. In our study we use dorsal percutaneous technique in 20 patients (57.14%), 9 patients (25.71%) with volar percutaneous approach and 6 patients (17.14%) with open volar approach. Mahmoud and Koptan [22] used a volar approach to percutaneously deliver a headless compression screw into 27 patients. Postoperative CT scans demonstrated fracture union in all 27 patients, and no patient underwent revision surgery. Interestingly, 14 of their patients had extensive preoperative resorption (but no deformity) of  $>5$  mm. In our study we use post-operative x-ray for assessment of union. Both Galal Mohamed Mansour Hegazy [23] and John T. Capo et al [24] used both dorsal percutaneous and volar percutaneous approaches with no difference in results.

Our results showed that, according to range of motion, the mean preoperative wrist flexion improved by  $53^\circ$  after fixation and the mean preoperative wrist extension improved by  $44.14^\circ$  post operatively. This is almost similar to study of M. Mahmoud et al [22] who performed screw fixation without bone graft in 27 patients with established non-union fracture of the scaphoid, The mean pre-operative range of movement was improved by  $60.7^\circ$  ( $45^\circ$  to  $80^\circ$ ),  $65.7^\circ$  ( $55^\circ$  to  $80^\circ$ ) for extension, flexion respectively.

In contrast to Galal Mohamed Mansour Hegazy [23] performed study in 30 patients with scaphoid non-union fractures, there were 24 male and 6 female patients with an average age of 23 years (range 16–45 years). There were 21 right-sided fractures and 9 left-sided fractures. In these patients the non-union healed 3 months after the revision procedure. Clinical follow-up was at 9 months (range 12–23) postoperatively. The average DASH score (disabilities of the arm, shoulder, and hand) at final follow-up was 8 (range 0–16). Average wrist ROM (range of motion) was extension of 71 degrees (range 50–80) and flexion 74 degrees (range 55–90).

Our results again supported with John T. Capo et al [24] performed study in 12 patients with scaphoid non-unions of an average duration of 8.7 months.

This variation in the results may be due to the difference in sample size, or maybe related to the experience of the operating surgeon.

Also, our study supported with Taskin Altay et al [25] performed study in thirty-three patients underwent a percutaneous screw fixation without bone graft for delayed or non-union scaphoid fractures. The mean duration of fractures was 7.6 months (range, two to 36 months). Fractures between

two and three months were described as delayed union and older than three months as non-union. All patients returned to their employment without pain but with slight decrease (10 % compared to the uninjured side) in range of motion or grip strength in 13 patients. In nine patients both grip strength and range of motion were greater than the normal wrist.

Also supported with Jeremy S Somerson et al [26] who performed study in 17 patients treated for scaphoid fibrous non-union by the senior authors using compression screw fixation without bone grafting.

In our study 34 of the 35 (97%) fractures united successfully with no additional procedures. These fractures achieved radiographic union at an average of 4 months. One patient required revision fixation, which consisted of repeat screw fixation with additional bone graft, this patient was diabetic. In this patient fracture healed 4 months after the revision procedure. Also, Galal M. Mansour Hegazy [23] in his study 25 patients achieved radiographic union at an average of 4 months (range 3–6 months) post-screw fixation. 5 patients required revision fixation, which consisted of ORIF by compression headless screw and bone grafting. Also, John T. Capo et al [24] performed study on 12 patients. The Result was Eleven of the 12 (92%) fractures united successfully with no additional procedures. One patient with sickle cell anemia required revision fixation, which consisted of repeat percutaneous fixation and bone grafting. In this patient his non-union healed 3 months after the revision procedure.

The limitations of the study are the relatively small number of patients, and the lack of control group to compare the results of scaphoid screw fixation without bone graft versus scaphoid fixation with bone graft. Therefore we can only speculate about functional outcome of scaphoid fixation without bone graft.

## **Conclusion**

We concluded that fixation with Herbert screw without bone graft for delayed union and non-union scaphoid fractures, provides satisfactory results with a high union rate, early return of function and minimal complications.

Also, that extensive resorption at the fracture site is not an absolute indication for bone grafting, and that percutaneous fixation alone will eventually produce healing of non-united displaced fractures of the scaphoid regardless of the size of the gap, unless there is a humpback deformity.

## References

1. Rettig AC, Patel DV. Epidemiology of elbow, forearm, and wrist injuries in the athlete. *Clin Sports Med* 1995; 14: 289-97.
2. Geissler WB. Carpal fractures in athletes. *Clin Sports Med* 2001; 20: 167-88.
3. Haisman JM, Rohde RS, Weiland AJ. Acute fractures of the scaphoid. *Instr Course Lect* 2007; 56: 69-78.
4. Kozin SH. Incidence, mechanism, and natural history of scaphoid fractures. *Hand Clin* 2001; 17: 515-24.
5. Van Tassel DC, Owens BD, Wolf JM. Incidence estimates and demographics of scaphoid fracture in the U.S. population. *J Hand Surg Am* 2010; 35: 1242-5.
6. Young VL, Higgs PE. The injured wrist. In: Martin DS, Collins ED, eds. *Manual of Acute Hand Injuries*. St. Louis: Mosby, 1998: 404-33.
7. Simonian PT, Trumble TE. Scaphoid nonunion. *J Am AcadOrthoSurg* 1994; 2: 185-91.
8. Jones DB Jr, Moran SL, Bishop AT, Shin AY. Free-vascularized medial femoral condyle bone transfers in the treatment of scaphoid nonunions. *PlastReconstrSurg* 2010; 125: 1176-84.
9. Slade JF 3rd, Geissler WB, Gutow AP, Merrell GA. Percutaneous internal fixation of selected scaphoid nonunions with an arthroscopically assisted dorsal approach. *J Bone Joint Surg Am* 2003; 85-A (Suppl 4): 20-32.
10. Kim JK, Kim JO, Lee SY. Volar percutaneous screw fixation for scaphoid waist delayed union. *ClinOrthopRelat Res* 2010; 468: 1066-71
11. Hove LM. Epidemiology of scaphoid fractures in Bergen, Norway. *Scand J PlastReconstrSurg Hand Surg*. 1999 Dec;33(4):423-6.
12. Tang A, Varacallo M. Statpearls [Internet]. Statpearls Publishing; Treasure Island (FL): Dec 13, 2018. Anatomy, Shoulder and Upper Limb, Hand Carpal Bones.
13. Erwin J, Varacallo M. Statpearls [Internet]. Statpearls Publishing; Treasure Island (FL): Apr 24, 2020. Anatomy, Shoulder and Upper Limb, Wrist Joint.
14. Mallee WH, Wang J, Poolman RW, Kloen P, Maas M, de Vet HC, Doornberg JN. Computed tomography versus magnetic resonance imaging versus bone scintigraphy for clinically suspected

scaphoid fractures in patients with negative plain radiographs. *Cochrane Database Syst Rev.* 2015 Jun 05;(6):CD010023.

15. Karantanas A, Dailiana Z, Malizos K. The role of MR imaging in scaphoid disorders. *EurRadiol.* 2007 Nov;17(11):2860-71.

16. Yin ZG, Zhang JB, Kan SL, Wang XG. Diagnostic accuracy of imaging modalities for suspected scaphoid fractures: meta-analysis combined with latent class analysis. *J Bone Joint Surg Br.* 2012 Aug;94(8):1077-85.

17. Doornberg JN, Buijze GA, Ham SJ, Ring D, Bhandari M, Poolman RW. Nonoperative treatment for acute scaphoid fractures: a systematic review and meta-analysis of randomized controlled trials. *J Trauma.* 2011 Oct;71(4):1073-81.

18. Yin ZG, Zhang JB, Kan SL, Wang P. Treatment of acute scaphoid fractures: systematic review and meta-analysis. *Clin. Orthop. Relat. Res.* 2007 Jul;460:142-51.

19. Buijze GA, Doornberg JN, Ham JS, Ring D, Bhandari M, Poolman RW. Surgical compared with conservative treatment for acute nondisplaced or minimally displaced scaphoid fractures: a systematic review and meta-analysis of randomized controlled trials. *J Bone Joint Surg Am.* 2010 Jun;92(6):1534-44.

20. Symes TH, Stothard J. A systematic review of the treatment of acute fractures of the scaphoid. *J Hand SurgEur Vol.* 2011 Nov;36(9):802-10.

21. Modi CS, Nancoo T, Powers D, Ho K, Boer R, Turner SM. Operative versus nonoperative treatment of acute undisplaced and minimally displaced scaphoid waist fractures--a systematic review. *Injury.* 2009 Mar;40(3):268-73.

22. M Mahmoud , W Koptan. Percutaneous screw fixation without bone grafting for established scaphoid nonunion with substantial bone loss. *J Bone Joint Surg Br* 2011 Jul;93(7):932-6. Doi: 10.1302/0301-620X.93B7.25418.

23. Galal Mohamed Mansour Hegazy. Percutaneous screw fixation of scaphoid non-union without bone grafting. *aamj*, vol10, no4, oct 2013 – suppl 2.

24. John T. Capo MD1, Ben Shamian MD2 and Marco Rizzo MD3. Percutaneous Screw Fixation without Bone Grafting of Scaphoid Non-Union. *IMAJ • VOL 14 • december 2012.*

25. Taskin Altay, IzgeGunal, CemilKayali, and MuhittinSene. Dorsal percutaneous screw fixation of delayed or non-union of scaphoid fractures. *IntOrthop*. 2014 May; 38(5): 1007–1010. Published online 2014 Feb 7. Doi: 10.1007/s00264-014-2282-5
26. Jeremy S. Somerson, Daniel J. Fletcher, Ramesh C. Srinivasan, and David P. Green. Compression screw fixation without bone grafting for scaphoid fibrous non-union. *Hand (N Y)*. 2015 Sep; 10(3): 450–453. Published online 2015 Feb 18. Doi: 10.1007/s11552-015-9741-3
27. Strel R. Percutaneous screwing of the navicular bone of the hand with a compression drill screw (a new method). *ZentralblChir* 1970; 95: 1060-78.
28. Bond CD, Shin AY, McBride MT, Dao KD. Percutaneous screw fixation or cast immobilization for non-displaced scaphoid fractures. *J Bone Joint Surg Am* 2001; 83:483-8.
29. McQueen MM, Gelbke MK, Wakefield A, Will EM, Gaebler C. Percutaneous screw fixation versus conservative treatment for fractures of the waist of the scaphoid: a prospective randomised study. *J Bone Joint Surg Br* 2008; 90: 66-71.
30. Bushnell BD, McWilliams AD, Messer TM. Complications in dorsal percutaneous cannulated screw fixation of nondisplaced scaphoid waist fractures. *J Hand Surg Am* 2007; 32: 827-33.
31. Kawamura K, Chung KC. Treatment of scaphoid fractures and nonunions. *J Hand Surg Am* 2008; 33: 988-97.
32. Wozasek GE, Moser KD. Percutaneous screw fixation for fractures of the scaphoid. *J Bone Joint Surg Br* 1991; 73: 138-42.
33. Ledoux P, Chahidi N, Moermans JP, Kinnen L. Percutaneous Herbert screw osteosynthesis of the scaphoid bone. *ActaOrthopBelg* 1995; 61: 43-7.