

CLINICAL ARTICLE

Clinical and Epidemiological Features of Scaphoid Fracture Nonunion: A Hospital-Based Study in Beijing, China

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Objective: Studies exploring the epidemiological characteristics of scaphoid fracture nonunion are important to understand the causes and lead to effective prevention strategy. However, such knowledge is limited especially in China. This study aims to reveal the clinical and epidemiological features of scaphoid fracture nonunion in Chinese patients.

Methods: This was a retrospective study, which was based on patients with scaphoid fracture nonunion treated in a Chinese national orthopedic referral center from 1 August 2009 to 1 August 2020. The basic demographic and clinical characteristics, including gender, age at diagnosis of scaphoid fracture nonunion, dominant hand, the location of fracture, the side, the causes of the injury, age of the injury, age of the treatment for scaphoid fracture nonunion, and the delay period, were retrieved from the medical records. The patients were divided into a non-delay group and a delay group based on whether they had visited the doctor within 1 month after the injury. Scaphoid fracture was classified into the proximal, waist, and distal fractures according to the location. The *t*-test or Mann–Whitney U test was used to compare the difference between groups when the dependent variable is continuous, while a chi-square test was used when the dependent variable is categorical.

Results: A total of 363 patients were included in this study. The mean age at the diagnosis of scaphoid fracture nonunion was 32 (ranging from 14 to 78). Waist fracture nonunion (76.5%) was most common. Among the 169 patients who sought medical care within 1 month after the injury (non-delay group), more than half (90 cases) were misdiagnosed. 23 cases could not recall the injury, so the time of delay could not be determined. Among the 171 patients who did not seek medical care for acute injury (delay group), the average time was 52 months between the initial injury and the treatment. The proportion of waist nonunions was higher among patients in the delay group than that in the non-delay group.

Conclusions: Nonunion of scaphoid fracture is caused mainly by delayed treatment and misdiagnosis in China, suggesting that timely treatment and improved diagnosis could lower the prevalence. The fracture location may be a factor contributing to the delaying of seeking medical care.

Key words: Epidemiology; Misdiagnosis; Nonunion; Scaphoid fracture

Introduction

Scaphoid fracture is the most common fracture in the carpus, accounting for 90% of carpal fractures^{1–3}. Scaphoid fracture is relatively prone to nonunion due to its complex geometry and poor blood supply⁴. Zura and colleagues performed epidemiological research of fracture nonunion in

18 human bones and found that the site with the highest nonunion was the scaphoid (15.5%), followed by the tibia and fibula (14%) and femur (13.9%)⁵. The treatment of scaphoid fracture has improved greatly since the 1950s, but nonunion of scaphoid fractures is still a difficult clinical problem. Duppe *et al.*⁶ found osteoarthritis in 56% of the

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nonunion cases after 36 years compared with 2% of the healed fractures. More and more attention was paid to nonunion of scaphoid fracture because it could decrease the function of the wrist and greatly affect the patients' life quality⁷⁻⁹. The nonunion rate of scaphoid fracture in the literature was 10%–40%^{10,11}.

If all bones heal by the same process, why do scaphoid fractures difficult to heal? Several risk factors for scaphoid nonunion are based more on tradition and wisdom than on scientific data. Failure to seek medical attention after a fracture (for instance, mistaking it as a sprain) is considered a risk factor for scaphoid nonunion¹². Wong and von Schroeder¹³ studied 96 patients with 99 scaphoid fracture nonunions and found that more than half of them did not receive standard initial treatment for acute injuries and presented late for initial treatment, or they presented much later due to secondary symptoms or re-injury. Many minimally displaced fractures are not visible on radiographs (at least initially),^{14,15} and these ignored fractures can also be a risk for nonunion¹⁶. Also, proximal pole fractures seem to be at a higher risk of nonunion and avascular necrosis (AVN). The traditional explanation is that a decreased arterial supply to the proximal pole makes fractures in that area more likely to progress to nonunion and limits the potential healing¹⁷.

Scaphoid nonunion not only brings a physical and mental suffering but also often an economic burden on both the patient and the medical system. Knowledge about its

epidemiological characteristics is useful in the clinical care of scaphoid fracture nonunions. There are some epidemiological reports on scaphoid fracture nonunion in Western countries,^{13,18,19} but the study of clinical and epidemiological features of scaphoid fracture nonunion in China is lacking until recently.

In this retrospective study, we aim to investigate the clinical and epidemiological features of scaphoid fracture nonunion in China. The patients were divided into non-delay and delay groups based on whether they had visited the doctor within 1 month after the injury. We explored whether patients in the delay group had different clinical characteristics than those in the non-delay group.

Methods

This study was approved by the Ethics Committee of Beijing Ji Shui Tan Hospital where the authors work at (the ethics case number: 202201-01). All methods were carried out in accordance with relevant guidelines and regulations, and informed consent was obtained from all participants and parents, or legally authorized representative of minor participants.

The medical records of the patients treated for scaphoid fracture nonunion in the hospital between 1 August 2009 and 1 August 2020 were reviewed. The information was collected and reviewed by two surgeons who had worked in orthopedic department for 2 years and 3 years. If the

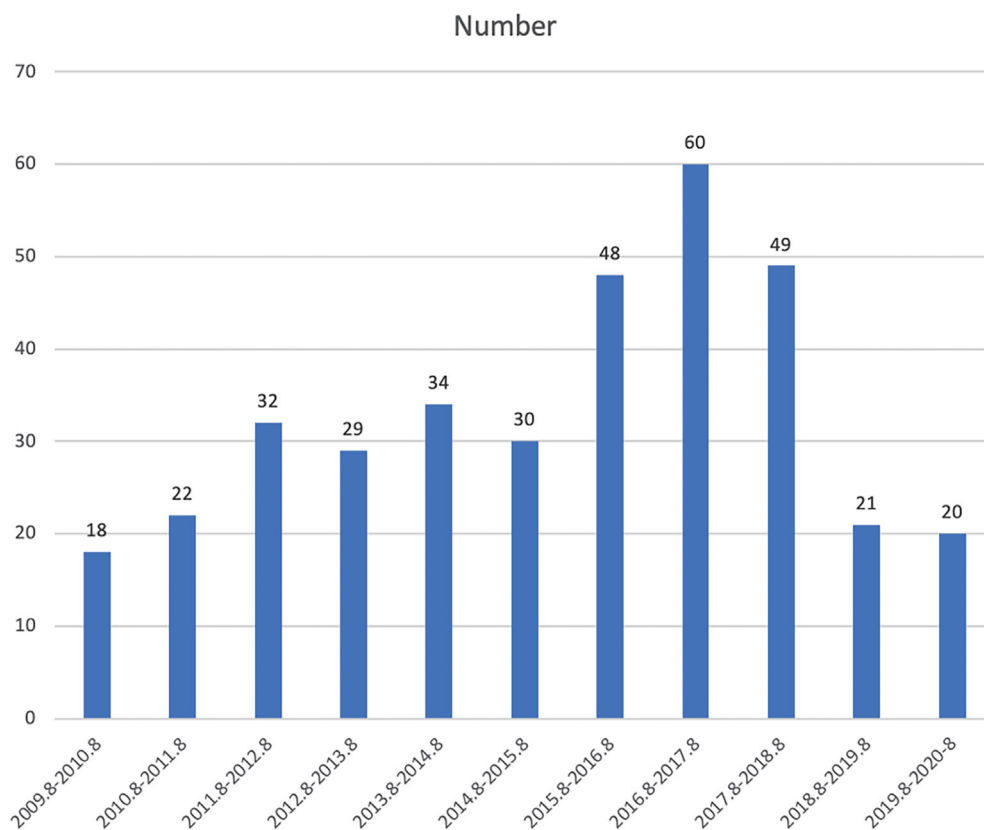


Fig. 1 The number of patients with scaphoid fracture non-union treated in our hospital in each year

information was incomplete, attempts were made to contact the patient. To further ensure the accuracy of the data, the information collected by the two surgeons was reviewed independently by another orthopedic surgeon who had worked in orthopedic department for 4 years. There was no discrepancy between the two surgeons who did the initial check, thus the inter-class correlation coefficient was 1.0.

The inclusion criteria included: (i) the diagnosis of non-union was at least 6 months after injury with typical radiographic signs of nonunion (such as widening of the fracture cleft, cyst formation, and sclerosis of the fracture surfaces) on X-ray images and/or CT images; (ii) the information collected in the case records or by contacting the patients was completed for analysis; and (iii) for the patients who could not recall the injury, typical radiographic signs of scaphoid non-union and stage I of scaphoid nonunion advanced collapse (arthrosis of the radial styloid) were needed.

The exclusion criteria included: (i) scaphoid fracture were less than 6 months; (ii) scaphoid fracture union was approved during the operation for the nonunion; and (iii) the information was incomplete for analysis.

A delay in treatment is defined if the time from injury to first medical assessment was greater than 1 month. All the patients were divided into two groups: the non-delay group and the delay group. The patients in the non-delay group who have received an x-ray plain film examination during the first medical assessment were further divided into two subgroups: diagnosed group and mis-diagnosed group. The patients in the non-delay group are divided into treatment group and non-treatment group according to whether they had been treated (including immobilization by cast /splint or surgery) or not. The scaphoid fracture was classified as proximal (proximal 1/3), waist (middle 1/3), and distal (distal 1/3) fracture according to the fracture location²⁰.

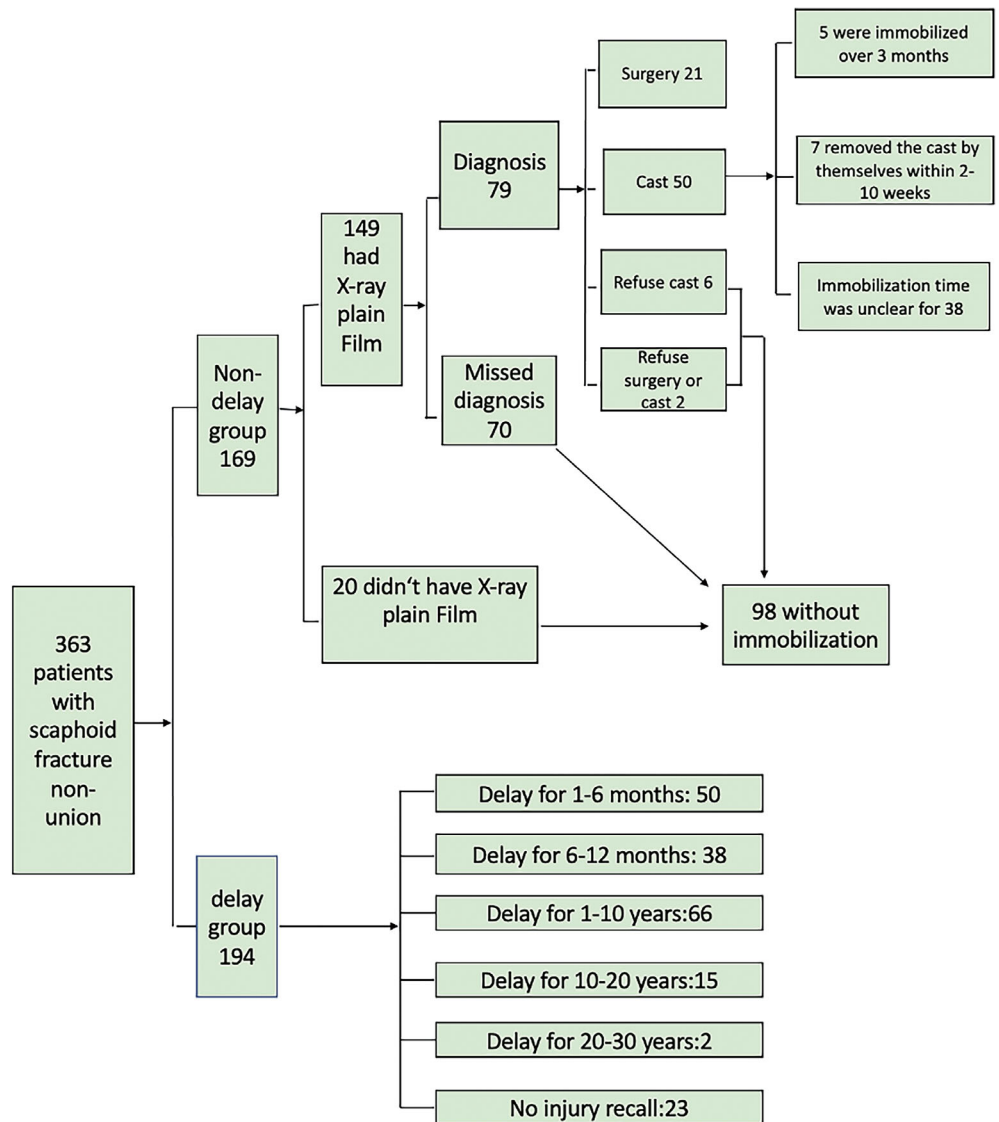


Fig. 2 Summary of presentation and initial management of 363 patients with scaphoid fracture nonunion

TABLE 1 Clinical and epidemiological features of the patients with scaphoid fracture nonunion

	Non-delay group (169)	Delay group (194)	Total Number	T value/X ² value ^a	P value
Mean age(years)	32.2	31.8	363	0.31	0.76
Gender				0.29	0.59
Male	156	176	332		
Female	13	18	31		
Side				0.05	0.83
left	71	85	156		
right	98	112	210		
Dominant hand				0.44	0.51
Yes	101	111	212		
No	68	86	154		
Fracture type ^c				7.88	0.02 ^b
Proximal	26	19	45		
Waist	118	162	280		
Distal	25	16	41		

Notes: ^aT value for continuous variables and X² value for categorical variables.; ^bP < 0.05 was considered to be significant.; ^cThree patients presented with bilateral nonunion, two patients suffered bilateral waist nonunion, and one patient suffered left distal pole nonunion and right waist nonunion.

Observation Indicators

The basic demographic and clinical characteristics, including gender, age at the diagnosis of scaphoid fracture nonunion, dominant hand, the location of fracture, side, the causes of the injury, age of injury, age of treatment for scaphoid fracture nonunion in our hospital, and the delay period, were retrieved from the medical records. We further explored in detail what kind of diagnostic techniques and treatment methods were used when patients visited medical care after the initial acute injury.

Statistical Analysis

Descriptive data were presented as numbers and percentages for categorical variables. The distribution of gender, side, dominant hand, fracture location, and the cause of the injury was accessed. The *t*-test was used to compare the difference between groups for continuous variables with a normal distribution, whereas the Mann–Whitney U test was used for

continuous variables without normal distribution. Chi-square test was used to compare the proportion of different locations of scaphoid fracture. The reported *P* values are two-sided. A *P* value less than 0.05 was considered to be significant. The analyses were done with SPSS (version 25 for Windows, Chicago, IL, USA).

Results**The Clinical and Epidemiological Features of Scaphoid Fracture Nonunion**

A total of 363 patients (332 males and 31 females) were diagnosed with scaphoid fracture nonunion from this study. The mean age of the patients was 32. The annual distribution of patients is shown in Fig. 1. Among them, three patients were presented with bilateral nonunion. The initial diagnosis and treatment are shown in Fig. 2. In total, 194 patients (the delay group) did not seek medical treatment within 1 month

TABLE 2 The characteristics of the patients who could recall a history of injury

	Non-delay group	Delay group	T value/X ² value ^a	P Value
Number	169	171		
Mean age of the injury(years)	28.6	26.4	1.90	0.06
Mean age of treatment for nonunion(years)	32.2	30.3	1.49	0.14
Mean time of delay (months)	45.5	52.0	-0.85	0.40
Causes of injury			13.60	0.02 ^b
Fall	121	133		
Traffic accident	6	0		
Machine injury	6	10		
Fall from a high place (above 2 meters)	6	1		
Sport injury	27	27		
Knife cut	1	0		
Crush by heave object	2	0		

Notes: ^aT value for continuous variables and X² value for categorical variables.; ^bP < 0.05 was considered to be significant.

TABLE 3 Relationship between the diagnosis of scaphoid fracture and the location of the fracture

	Proximal	Waist	Distal	X ² value	P value
Diagnosed	11	58	10	0.45	0.80
Misdiagnosed	11	48	11		

after the injury, which accounted for 53.4% of the nonunion cases. Among them, 50 patients sought medical treatment within 6 months after the injury, and 121 patients sought medical treatment more than 6 months after the injury, ranging from 6 months to 30 years. The average time from the injury to medical treatment was 52 months. A total of 23 cases could not recall the injury, so the time of delay could not be determined. For patients in the non-delay group, missed diagnosis accounted for 53.3% of scaphoid fracture nonunion (including 20 patients who did not have an X-ray examination and 70 patients whose scaphoid fractures were missed on X-ray films). Sixteen cases were complicated with injuries at other sites, including distal radial fracture in four cases, lunate dislocation in four cases, scaphoid fracture in two cases, radial head fracture in two cases, horrible triad of elbow in one case, tendon rupture in one case, pelvic fracture combined with femoral neck fracture in one case, and scapholunate ligament injury in one case. The scaphoid fracture was not diagnosed in the initial diagnosis for three cases with multiple injuries.

Clinical Features of Delay and Non-delay Groups

There were no significant differences in age at diagnosis and treatment, the side of the hand, and the proportion of dominant hand between delay and non-delay groups. There were 45 proximal fractures (12.3%), 280 waist fractures (76.5%) and 41 distal fractures (11.2%). The proportion of proximal and distal fractures was significantly higher in the non-delay group than in the delay group (X² value:7.88, P-value: 0.02), as shown in Table 1.

For 340 patients whose time of injury could be determined, there was no significant difference between the non-

delay group and the delay group when comparing the age of injury, the age of treatment for scaphoid fracture nonunion in our hospital, and the delay period. The number of patients with different causes of injury is shown in Table 2.

Of the 169 patients in the non-delay group, 149 patients received plain radiograph examination at the first treatment for the injury. Misdiagnosis was noted for 70 patients (47.0%). There was no significant difference in the proportion of fractures at different locations between mis-diagnosis and diagnosis groups (X² value: 0.45, P value: 0.80), as shown in Table 3.

In the non-delay group, 71 patients were treated for scaphoid fractures, including 21 patients who have received surgical treatment and 50 patients who were immobilized by cast or splint, but nonunion still occurred. Among them, 38 patients could not recall the time of immobilization. Five patients were immobilized for more than 3 months, and seven patients removed the cast or splint by themselves without any review at 2–10 weeks after the injury. There was no significant difference in age of injury, age of treatment for scaphoid fracture nonunion in our hospital and the delay period between the treatment group and non-treatment group (details in Table 4).

Discussion

In this study, we explored the clinical and epidemiological pattern among patients with scaphoid fracture nonunion who were admitted to a Chinese orthopedic referral center during the past 11 years. We found that delayed medical treatment and initial mis-diagnosis account for the major part of scaphoid fracture nonunion among patients treated in our hospital. The proportion of proximal and distal fractures was significantly higher in the non-delay group than in the delay group.

The Clinical and Epidemiological Features of Scaphoid Fracture Nonunion

The average age of the patients with scaphoid fracture nonunion was 32 years old. Waist fracture nonunion (280 cases, 76.5%) was the most common. We found that more than half of the cases were caused by delayed treatment (53%) which was higher than previously reported,^{13,18,19} suggesting that timely diagnosis and treatment could lower the prevalence of scaphoid fracture nonunion in Beijing, China. There were no significant differences in age at diagnosis and treatment, the side of the hand, and the proportion of dominant hand between delay and non-delay groups. The proportion of proximal and distal scaphoid fractures in the non-delay group was higher than that in the delay group, which may be related to the fact that the clinical symptoms of proximal and distal fractures were more severe than those of waist fractures.

The Potential Mechanisms for Scaphoid Nonunion

Several risk factors for scaphoid nonunion are based more on tradition and wisdom than on scientific data. In this study, the clinical and epidemiological features of scaphoid fracture nonunion in China were studied and the underlying factors contributing to scaphoid fracture nonunion in

TABLE 4 The relationship between treatment experience and the time of delay

	Non-treatment group	Treatment group	T value	P value
Case number	98	71		
Mean age of the injury(years)	27.9	29.5	-0.90	0.37
Mean age of treatment for nonunion(years)	31.9	32.5	-0.30	0.77
Mean time of delay (months)	48.3	39.0	0.84	0.40

Chinese patients were proposed based on the results. Factors contributing to scaphoid fracture nonunion in this study were classified into: patient factors, iatrogenic factors and biological factors.

Patient Factors Leading to Scaphoid Fracture Nonunion

Delayed treatment is an important factor leading to fracture nonunion. Eddeland *et al.*²¹ reported that the nonunion rate of scaphoid fractures with fracture displacement greater than 1mm was 92%, while the nonunion rate of scaphoid fractures with fracture displacement less than 1mm was 19%, which was significantly higher than other reports. Additionally, it was found that all nonunions happened in the patients that had not been immobilized within 4 weeks after injury. So early immobilization is very important for scaphoid fracture healing. It was confirmed that the time of surgical treatment of scaphoid fracture being more than 31 days from the time of injury was a risk factor for scaphoid fracture nonunion²² In this study, a total of 194 patients did not seek medical treatment within 1 month after the injury, which accounted for 53.4% of the nonunion cases. The rate of delay treatment (delay more than 1 month) of this study is higher than previous report. Heidsieck *et al.*¹⁹ reported a cohort of 101 scaphoid nonunion patients and found that 31% patients did not seek medical care within 4 weeks after the injury. Wong and von Schroeder¹³ reported a cohort of 88 scaphoid nonunion cases, 50% cases did not seek medical care within 4 weeks after the injury.

Studies have confirmed that not all patients with scaphoid fracture on x-ray have pain symptoms^{16,23}. Patients often do not visit the doctor because their symptoms are mild and the injury is mistaken as wrist sprains. In this study, we found that the proportion of proximal and distal scaphoid fractures in the non-delay group was higher than that in the delay group, which may be related to the fact that the clinical symptoms of proximal and distal fractures were more severe than those of waist fractures. Young patients may not seek treatment because they have stressful jobs and do not want the treatment to interfere with their work. Many patients said that the symptoms gradually disappeared without further treatment. In addition, we found that the diagnosis and treatment experience of acute scaphoid fracture did not significantly shorten the delay time of diagnosis and treatment of scaphoid fracture nonunion, which may be due to the slight symptoms of scaphoid fracture nonunion at an early stage.

Poor compliance is also an important factor leading to scaphoid fracture nonunion. In this study, eight patients refused to immobilize or take surgical treatment. Additionally, seven patients were initially immobilized for 2–10 weeks and removed the splint or cast by themselves.

Iatrogenic Factors Leading to Scaphoid Fracture Nonunion

In the cohort of 268 scaphoid nonunion patients reported by Reigstad *et al.*,¹⁸ 146 patients consulted a physician at the time of injury, and only 53 cases (36%) were diagnosed as

scaphoid fracture. Among 93 patients (with 94 scaphoid fractures) examined by a doctor at the time of injury, 60 had radiographs taken, the injury was interpreted as a sprain. The results of Reigstad *et al.* are consistent with our findings. In contrast to the current study, the relationship between misdiagnosis and the location of scaphoid was not further evaluated. The diagnosis of scaphoid fractures may be a challenge for the young doctor working in the emergency room. Many patients with scaphoid fractures were often mistaken for wrist sprain and did not receive an x-ray examination at the first visit, which was a strong reason for the misdiagnosis. This situation happened for 20 patients in this study. Also, the false-negative rate on x-rays is as high as 16% for patients undergoing X-ray examination². In this group, 70 scaphoid fractures were missed on initial radiographs. There was no significant difference in the proportion of fractures at different sites between the misdiagnosis group and the diagnosis group, so the difficulty in finding fractures at different sites of scaphoid was similar. Treatment of these patients with suspected scaphoid fracture and negative x-rays includes placing them in either a removable splint or an under elbow plaster cast. It is important to inform these patients of the possibility of a fracture and nonunion (10%). After 2 to 3 weeks, patients may be reviewed to see whether they still have clinical features suggestive of a scaphoid fracture. However, 70 patients did not receive immobilization or the re-examination using x-ray after 2 weeks of the injury, which was also an important factor of scaphoid fracture nonunion in our study.

For patients with multiple injuries, the scaphoid fracture could be misdiagnosed by doctors. In this group, 16 patients had multiple injuries, and missed diagnoses happened for three of them. Therefore, it is important to strengthen the training of medical staff and improve their vigilance of scaphoid fracture.

Biological Factors Leading to Scaphoid Fracture Nonunion

Similar to other fractures, the potential for scaphoid healing depends on the fracture site and blood supply. The nonunion rate of scaphoid fractures reported in the literature is usually consistent with 12% reported by Filan and Herbert²⁴ and 10% reported by Kawamura and Chung¹⁶. The nonunion rate of the proximal scaphoid is higher²⁵. Eastley *et al.*²⁶ performed a meta-analysis and found that the incidence of nonunion of proximal scaphoid fractures was 7.5 times higher than that of non-proximal fractures for the cases receiving conservative treatment. Nonunion of proximal scaphoid fractures accounted for 12.3% of the total cases in this group, which may be related to the low incidence of said fractures. Fracture displacement greater than 1mm and an angle greater than 15 degrees are reknowned risk factors for nonunion. Of the patients (53.4%) in this group did not seek medical care at the time of injury. So, it was impossible to evaluate the displacement of acute scaphoid fractures for these patients. Nonunion may occur even in cases of scaphoid fracture that are identified early and properly treated¹³.

There were five patients who received regular conservative treatment, such as more than 3 months' immobilization by cast/splint and 21 patients who received surgical treatment in this group. The causes of the non-healing of these patients are unclear and worth exploring.

Strengths and Limitation

To our best knowledge, this was the first study on scaphoid fracture nonunion in China with the largest sample size for scaphoid fracture nonunion in a single center. This study revealed clinical and epidemiological features of scaphoid fracture nonunion in China, which was based on clinical data for more than 11 years. A few limitations should be kept in mind when we interpret the current findings. First, all the patients were identified from a single hand clinic center, which might not be representative for the Chinese population. In future work, our study may involve multiple centers from different cities, which could increase the size of the dataset. The second limitation was that this study was a retrospective epidemiological study and there may be recall bias. Third, this study was not a case control study and could not compare the difference of risk factors between scaphoid fracture union and nonunion.

Conclusions

The nonunion of scaphoid fracture is caused by many factors, among which delayed medical treatment and initial misdiagnosis account for the majority in this single hospital-based study in China. There is a strong need for better edu-

cation on the subject of scaphoid fracture and its associated nonunion. The fracture location may be a factor contributing to the delay of seeking medical care for acute scaphoid fracture. Other analytic studies, such as case control study or cohort study, are needed for future research to analyze the risk factors for scaphoid nonunion.

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Authors' Contributions

All authors had full access to the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis: conceptualization, Yaobin Yin, Bo Liu and Shanlin Chen; methodology, Yaobin Yin, Ke Xu, Nan Zhang and Zhe Yi; acquisition of data: Ke Xu, Nan Zhang, Zhe Yi; resources, Bo Liu, Shanlin Chen and Yaobin Yin; writing—original draft, Yaobin Yin; review and editing, Yaobin Yin and Shanlin Chen; supervision, Shanlin Chen; and funding Acquisition, Yaobin Yin.

Disclosure Statement

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