A Strategy for Treating Scaphoid Fractures Based on Radiographic Classifications

Kazuo Ikeda¹, Naoki Osamura¹, and Kaoru Tada²
¹Department of Orthopaedic Surgery, Kanazawa Medical Center, Kanazawa, Japan
²Department of Orthopaedic Surgery, Kanazawa University, Takaramachi, Kanazawa, Japan

Abstract

We classified scaphoid fractures according to radiographic findings as linear, cystic, and sclerotic or displaced type. We treated 106 scaphoid fractures using Acutrak screws from 2003 to 2016. 48 Linear, 38 cystic, and 20 sclerotic or displaced types were included in this study. Linear and cystic types did not have a displacement of more than 2 mm. If the fracture line had a sclerotic zone thicker than 1 mm or displaced more than 2 mm, it was classified as sclerotic or displaced. According to our strategy, we treated linear fractures using a screw fixation, cystic fractures with a screw fixation without bone graft and a low-intensity pulsed ultrasound (LIPUS), and sclerotic or displaced fractures with an open reduction, a bone graft, a screw fixation and LIPUS. Bone union was achieved in 99 out of 106 hands, meaning a 93.3% success rate, with 91.6% in linear, 97.3% in cystic, and 90.0% in sclerotic or displaced type. The average period until bone union was: 2.3 months in linear, 3.2 months in cystic, and 4.5 months in sclerotic or displaced type. Since we achieved over a 90% union rate, our strategy for treating scaphoid fractures is appropriate.

Keywords: Bone Graft; Cystic Lesion; Delayed Union; Scaphoid Fracture

Abbreviations

LIPUS: Low-Intensity Pulsed Ultrasound; CT: Computed Tomography; MRI: Magnetic Resonance Imaging.

Introduction

Although the most popular classification system for scaphoid fractures is Filan and Herbert's classification [1,2], this classification is not linked to any treatment strategies. Since there are no classification systems that include a treatment strategy, we proposed a new classification system for treating scaphoid fractures based on radiographic findings, categorizing them as linear type, cystic type, and sclerotic or displaced type [3] (Figure 1). While Filan and Herbert’s classification[1], defines a delayed union as a fracture occurring at least six weeks before surgery, the length of time before surgery did not affect our classification. Our strategy for treating linear fractures is using a screw fixation, for cystic fractures is a screw fixation without bone graft and a low-intensity pulsed ultrasound (LIPUS), and for sclerotic or displaced fractures is an open reduction, a bone graft, a screw fixation and LIPUS (Table 1). With the development of new screws for scaphoid fractures, the union rate has risen to 94% [4]; or 84% [5] even including cases of non-union. If the union rate is around 90%, the strategy is considered as valuable. The purpose of this study is to verify the strategy for treating scaphoid fractures using our classification.

Methods

The institutional review board's approval was not required as this was a retrospective non-randomized study [IRB approval 2017-23]. We treated 107 scaphoid fractures using Acutrak screws [Acumed, USA] from 2003 to 2016. Dislocation fracture, necrosis, and pathological fractures were excluded. One patient discontinued treatment because of personal reasons. We retrospectively studied 106 hands in 104 patients of scaphoid fractures in 96 male and 8 female patients ranging in age from 14 to 75 years old [average, 26.8 years]. Radiograms were taken of the following views: postero-anterior, lateral wrist, scaphoid [postero-anterior in ulnar deviation], and oblique with 45 to 60 degrees of pronation [6]. A computed tomography (CT) scan was also taken in cases that were difficult to classify using only radiograms. Bone union was estimated from all four views and the CT scans. There were six distal tubercle fractures, 89 waist fractures, and 11 proximal pole fractures (Table 1). Using the radiographic findings, we classified the scaphoid fractures as linear type, cystic type, and sclerotic or displaced type [3] (Figure 1). Linear and cystic fractures did not

<table>
<thead>
<tr>
<th>Fracture Type</th>
<th>Distal</th>
<th>Waist</th>
<th>Proximal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear type</td>
<td>4 (0)</td>
<td>42 (3) Acm.</td>
<td>2 (1) Acm.</td>
<td>48 (4) 95.6%</td>
</tr>
<tr>
<td>Cystic type</td>
<td>1 (0)</td>
<td>30 (0)</td>
<td>7 (1) Acm.</td>
<td>38 (1) 97.3%</td>
</tr>
<tr>
<td>Sclerotic or Displaced type</td>
<td>1 (0)</td>
<td>17 (0)</td>
<td>2 (2) Acm.</td>
<td>20 (2) 90.1%</td>
</tr>
<tr>
<td>total</td>
<td>6 (0)</td>
<td>89 (3) 95.6%</td>
<td>11 (4) 106 (7) 52.3%</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Results of the scaphoid fracture treatments divided by fracture location and strategy. [ ]: number of non-union cases % union rate. [ ]: number of reoperation cases % re-operation rate.
have a displacement of more than 2 mm. When the fracture site showed only linear features, it was classified as linear type. When the fracture site showed cystic features, it was classified as cystic type. When the fracture site had a sclerotic zone thicker than 1 mm or displaced more than 2 mm, it was classified as sclerotic or displaced type [Table 2]. There were 48 linear, 38 cystic, and 20 sclerotic or displaced fractures. We did not use the categories of acute or delayed, as in common classifications [1], because the period before surgery did not affect our classification or treatment strategy.

The treatment strategy for linear fractures was only a percutaneous Acutrak standard screw fixation, for cystic fractures was an Acutrak standard screw fixation without bone graft and LIPUS. If the patient had a small physique or in cases of distal tubercle fractures, an Acutrak mini screw was used. The treatment strategy for sclerotic or displaced fractures was an open reduction, a block iliac bone graft, using an Acutrak mini screw fixation and LIPUS [Table 2]. If a bone defect was not seen after reduction, a bone graft was not necessary. However, in our study, we performed a bone graft in every case. When the fracture location was proximal, an Acutrak mini or micro screw was inserted from the proximal pole by a dorsal approach. LIPUS was applied for 20 minutes per day until bone union was achieved. LIPUS consisted of a 1.5 MHz ultrasound wave pulsed at 1 kHz with a 20% duty cycle at an intensity of 30 mW/cm² spatial average temporal average [7]. Regarding cystic fractures, the union periods of waist fractures with or without LIPUS were compared [Figure 2]. Since two cases took more than one year to achieve bone union, 28 cases were included in this study. Bone union times with and without LIPUS were evaluated using the Mann-Whitney U test and the average and standard deviations were calculated. Probabilities of less than 0.05 were accepted as significant. The length of time before surgery was compared to the length of time until bone union in the three types of fractures [Figure 3]. Two cases of linear fractures, two cases of cystic fractures and three cases of sclerotic or displaced fractures were excluded from this study because bone union took more than one year.

### Results

Bone union was achieved in 93.3% of the fractures, with 91.6% in the linear, 97.3% in the cystic, and 90.0% in the sclerotic or displaced fractures [Table 1]. The average periods for bone union were as follows: 2.3 months ± 1.1 months [1.0–5.0] in the linear, 3.2 ± 1.4 months [1.2–11.9] months in the cystic and 4.5 ± 2.1 months [2.5–11.0] in the sclerotic or displaced fractures. The average period for bone union in the 18 cases with LIPUS was 2.89 ± 1.40 months and in the 10 cases without LIPUS was 3.38 ± 1.39 months [Figure 2]. Although there were no significant differences between the two groups, the p-value was 0.07. There were seven cases which bone union was unsuccessful, three waist and four proximal pole fractures [Table 1]. Since four of the patients did not complain of any wrist pain, even with radio-graphically detected non-union, they did not desire further surgery. The other three cases needed a second operation to achieve bone union. The total re-operation rate

<table>
<thead>
<tr>
<th>Type [1]</th>
<th>Definition</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Displacement no more than 2 mm</td>
<td>percutaneous screw fixation</td>
</tr>
<tr>
<td>Cystic</td>
<td>Displacement no more than 2 mm Fracture site</td>
<td>percutaneous screw fixation without bone graft with</td>
</tr>
<tr>
<td></td>
<td>shows cystic void</td>
<td>LIPUS</td>
</tr>
<tr>
<td>Sclerotic or</td>
<td>Sclerotic zone thicker than 1 mm or Displacement</td>
<td>Open reduction and w/wo iliac bone graft with LIPUS</td>
</tr>
<tr>
<td>Displaced</td>
<td>more than 2 mm</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Strategy for treating scaphoid fractures according to Ikeda’s classification [3]. (This classification relies on X-ray findings. The time period following injury is not considered. LIPUS: Low-intensity pulsed ultrasound.)

![Figure 2](image-url) Period until union of cystic type waist fractures compare groups with and without low-intensity pulsed ultrasound (LIPUS). There is no significant difference between the two groups, but the p-value is 0.07.

![Figure 3A](image-url)  
A: In linear type. Although linear fractures resemble acute fractures, there were 6 linear fractures which were found more than one month after injury. There was a slight correlation of R²=0.046.

![Figure 3B](image-url)  
B: In cystic type. Although cystic fractures resemble delayed fractures, there were 4 cystic fractures which were found less than one month after injury. There was a correlation of R²=0.290.
was 2.8%, with 2.0% in the linear, 0% in the cystic, and 10.0% in the sclerotic or displaced fractures. The two proximal pole sclerotic or displaced fractures needed vascularized bone graft from distal radius in a second operation. One case of re-operation utilized a locking plate. The correlation between the time period until union and the time period before surgery was estimated [Figure 3]. In linear fractures, there was a slight correlation of $R^2 = 0.046$. In cystic fractures, there was a correlation of $R^2 = 0.290$. In sclerotic or displaced fractures, there was no correlation. All of the sclerotic or displaced fractures were discovered more than one month after injury. Magnetic resonance imaging [MRI] was used in seven cases of cystic fracture. Two of the cystic areas displayed a low signal in the T2 weighted imaging, indicating that the contents of the cystic lesion were fibrous tissue, and five of the areas showed a high signal in the T2 weighted imaging, indicating that the content of the cystic lesion were liquid. There was no significant difference between the bone union periods because the number of cases was too small.

**Representative Cases**

**Case 1:** A 16-year-old male was involved in a traffic accident and received a wrist injury. He visited our hospital 5 weeks after injury and the radiographic examination revealed a waist scaphoid fracture [Figure 4A]. This scaphoid fracture was classified as linear type. The CT showed a displacement of less than 2 mm [Figure 4B, C]. Therefore, a percutaneous Acutrak standard screw fixation was performed and bone union was achieved seven weeks after surgery [Figure 4D].

**Case 2:** A 17-year-old male fell down and injured his wrist. He visited our hospital four months after injury and the radiographic examination revealed a cystic type scaphoid fracture [Figure 5A]. The CT revealed a cystic defect at the waist but no displacement [Figure 5B, C]. An MRI of the cystic area revealed a high signal in the T2 weighted imaging, indicating that the contents of cystic lesion were fibrous tissue, and five of the areas showed a high signal in the T2 weighted imaging, indicating that the content of the cystic lesion were liquid. Therefore, a percutaneous Acutrak standard screw fixation was performed without bone graft and LIPUS [Figure 5E]. Bone union was achieved four months after surgery [Figure 5F].

**Case 3:** An 18-year-old male fell down and injured his wrist during a football game. He visited our hospital four months after injury. A radiographic examination revealed a cystic type scaphoid fracture [Figure 6A]. The CT showed a proximal pole cystic lesion [Figure 6B]. We performed a percutaneous screw fixation using an...
A 23-year-old male fell down during a sports activity and injured his wrist. He visited our hospital 3.5 months after injury. The radiographic examination revealed a linear type scaphoid waist fracture [Figure 7A]. We performed a percutaneous screw fixation using an Acutrak standard screw [Figure 7B], but the length of the screw was shorter than ideal. Two years later, an X-ray and CT showed non-union [Figure 7C, D]. Since the patient had no discomfort, he did not want further treatment.

**Discussion**

The most common classification system for scaphoid fractures is the Filan and Herbert’s classification [1,2]. It defines a delayed union as six weeks after injury. Treating a delayed union is more difficult than treating acute fractures [8], because the fracture line is usually sclerotic or the fracture site is displaced and angular deformity has started. Hence, the length of time between injury and treatment is considered to be very important. Although our study showed that there was a relationship between the period until bone union and the length of time after injury in linear fractures [Figure 3], bone union could be achieved even if the period before surgery was more than six weeks. While linear fracture resembles acute fractures, in our previous study there were six linear fractures which were found more than one month after injury [3]. In the current study, there were three cases of linear fractures discovered six weeks after injury. If there are no displacement or sclerotic changes at the fracture site which we define as linear type, the length of time between injury and treatment is not an important factor in determining a treatment strategy. Whether or not there is sclerotic change or displacement, however, is more important than the period before surgery in predicting the results. In our previous study, although the cystic fractures resemble delayed fractures, there were four cystic fractures which were found less than one month after injury [3]. In this study, there were also four cystic fractures which were found less than one month after injury. Therefore, we proposed a new classification system, not based on the period before surgery, but solely on radiographic findings. Since all of the sclerotic or displaced fractures were found more than one month after injury, they were considered non-union according to the standard classifications.

There were also four cases of asymptomatic non-union in our study. Since the patients did not complain any of pain or disability during activity of daily living, they did not desire further surgery [Figure 7]. Although CT scans clearly showed the non-union, there might have been a fibrous union that created good stability. Three cases out of 109 showed the asymptomatic nonunion that we described [9]. Although asymptomatic non-unions were considered unsuccessful, a second operation was not needed. Therefore, we believed that the re-operation rate is a better assessment than the non-union rate. In our study, the non-union rate was 6.7% but the re-operation rate was 2.8%. This means that our success rate should be seen as 97.2%. Hence, our strategy for treating scaphoid fractures based on radiographic findings instead of the length of time before surgery is appropriate.

In linear type, we recommend a percutaneous screw fixation. In another study, percutaneous screw fixations used for acute fractures, the same treatment we use for linear type [8]. They achieved bone union in an average of 2.6 months in 11 cases [10]. Since we achieved bone union in an average of 2.3 months in 48 hands including cases of delayed union, the results were almost the same as their study. Other authors have defined a fibrous union...
as having a sclerotic line of less than 1 mm thick and in correct alignment [11], which could be considered the equivalent of our delayed linear fracture. They used a percutaneous screw fixation in 15 cases of fibrous union and achieved bone union in every case in an average 3.5 months [11]. 21 cases of delayed linear fractures were also treated solely by screw fixation, and they all achieved union [12]. According to these papers [10–12], our strategy for treating linear fractures using a percutaneous screw fixation without bone graft instead of basing the treatment on the length of time before surgery, was demonstrated to be appropriate.

In cystic type, we recommend a percutaneous screw fixation without bone graft and LIPUS. Cystic lesions are considered to be a characteristic of delayed or non-union [13]. However, in our study, there were four cystic fractures that developed within one month after injury [Figure 3B]. Hence, the length of time between injury and treatment is not important in deciding a treatment strategy.

With the development of new screws for scaphoid fractures, union rates have risen to 94% [1], 90% [9], or 84% [2] even including cases of non-union. There is still some controversy concerning whether a bone graft is necessary for cystic type non-union. In reports that examined the appearance of cysts [13,14], the category of “cyst formation and sclerosis”, which includes bone resorption at the non-union interface, cyst formation, and maintained scaphoid alignment, could be considered the equivalent of our cystic type [13]. One study recommended a bone graft for fractures in this category and another report recommended curettage and filling with small cancellous bone chips for cystic defects [9]. From our previous results, we do not think a bone graft is necessary for cystic fractures, because there is no difference in the union rate of our cystic types between cases with [85%] and without [82%] bone grafting [3]. In addition, from an intraoperative view point, a cystic lesion does not always indicate a defect or instability at the fracture site [3]. Hence, we considered that stability is necessary to achieve bone union because cystic lesion has basically an ability of bone formation. In our study, the period for bone union in cystic fractures [3.2 months] was significantly longer than that of linear fractures [2.3 months]. For this reason, we applied LIPUS to cystic fracture to promote faster union [7]. Although we recommended using LIPUS after surgery, there was no significant difference in the period of bone union between treatment with and without LIPUS for [Figure 2]. If the number of cases increases in the future, there might be a significant difference.

In our study of sclerotic or displaced type, there were no acute fractures that occurred within one month of injury. Hence, sclerotic or displaced fractures could be considered the equivalent of delayed or non-union fractures in the other reports. Using iliac block bone grafts was the standard treatment method for angulated displaced scaphoid fractures [6,13]. In the 5246 cases scaphoid non-union reviewed, the union rate for those with bone grafts was 84% [13]. Out of 20 cases in our study, however, there were only two cases of non-union [90% union rate]. This means that our results were excellent when compared to other reports [4,5]. Hence, our strategy for treating sclerotic or displaced fractures, with a screw fixation with iliac block bone graft, is proven correct. In our previous study, we had 8 sclerotic or displaced proximal pole fractures that all achieved bone union [3]. However, in this current study, two fractures could not achieve bone union and needed a vascularized bone graft in a second operation. Hence we recently used a double-thread screw instead of Acurak screw in these cases [9]. According to another report, in fourteen cases needing screw fixation, there was non-union in 2 proximal pole fractures [15]. Also, in 53 cases of proximal pole fractures, the period until bone union was 14 ± 8 weeks, a very lengthy time [16]. Since it is difficult to achieve bone union in proximal pole fractures, a vascularized bone graft might be one of the options in the primary surgery. Especially when re-operation includes a difficult procedure such as re-screw fixation, plate fixation might be considered [17] [Table 1].

**Conflict of Interest**

There is nothing declare conflicts of interest of all listed authors.

**Acknowledgements**

The authors would like to thank Ms. Carla Curry Inoue for assistance in presenting this study.

**References**

*Corresponding author:* Kazuo Ikeda, Department of Orthopaedic Surgery, Kanazawa Medical Center, 1-1 Shimoishibikicho, Kanazawa, 920-8650, Japan. Tel: 81-76-244-5202; Fax: 81-76-222-2758; E-mail: ikeikemed@yahoo.co.jp.

Received Date: February 14, 2018, Accepted Date: March 19, 2018, Published Date: March 29, 2018.

Copyright: © 2017 Ikeda K et al. 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.