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Research Article:
Comparison of Computed Tomography Scan and Plain Radiograph for the Assessment of Postoperative Union in Patients Treated for Scaphoid Nonunion

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ABSTRACT

Background: The appropriate monitoring of union following the treatment of scaphoid nonunion is essential. However, there is no consensus regarding the optimal imaging modality for this evaluation.

Objectives: Here, we compared the reliability of plain radiographs with Computed Tomography (CT) scanning in determining the union of scaphoid following the scaphoid nonunion.

Methods: In this retrospective study, 25 patients, who underwent the surgical treatment of scaphoid nonunion and had both plain radiographs and CT images, were included. The surgical procedure included open reduction, illiac crest bone graft, and K-wire fixation. Two different observers assessed the healing of scaphoid nonunion by both imaging modalities and graded as healed or non-healed.

Results: The Mean±SD age of the patients was 29.1±6.8 years. The Mean±SD time interval from the operation to imaging was 6.5±2.5 months. Based on the plain radiographs, all patients achieved the scaphoid union. However, in the CT evaluation, 23(92%) patients showed the scaphoid union. Accordingly, CT images and plain radiographs agreed in 23 cases and disagreed in two cases. This difference was not statistically significant (P=0.5).

Conclusion: In a subset of patients, who underwent the operation for the treatment of scaphoid nonunion, plain radiographs might falsely confirm a scaphoid union. In these patients, a complementary CT evaluation might be helpful in the accurate assessment of scaphoid healing.

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1. Introduction

Scaphoid fracture is one of the most common fractures of the upper extremity that accounts for almost (60%) of all fractures of carpal bones [1, 2]. The unusual retrograde blood supply of scaphoid predisposes the nonunion event. Scaphoid nonunion occurs in (5-10%) of the scaphoid fractures, particularly in the displaced fractures [3, 4]. If inappropriately treated, scaphoid nonunion can result in carpal collapse and radiocarpal arthrosis, thereby complicating an already challenging situation [5]. For this reason, the appropriate monitoring of union following the treatment of scaphoid nonunion is essential [6].

The 3-dimensional (3D) anatomy of the scaphoid hampers the accurate assessment of fracture and degree of fragment displacement [7]. For this reason, the evaluation of the union of scaphoid fractures is difficult on a standard series of radiographs. Even so, plain radiographs continue to be the imaging study of choice for the evaluation of scaphoid union following the interventional management of scaphoid nonunion [8].

Although comparative studies evaluating the union of the scaphoid are traditionally based on plain radiographs, recent evidence reveals that the monitoring of healing progress of the scaphoid union to ensure the development of bridging bone across the fracture line is best detected by Computed Tomography (CT) scanning. CT scans allow for a 3D assessment of the trabecular architecture of the scaphoid with reformatting in multiple planes, and, thus, have proven to be more reliable and accurate in the evaluation of union [9, 10].

In this study, we aimed at comparing the CT scanning and plain radiograph to assess the scaphoid union in a series of patients, who underwent the operation for the treatment of scaphoid nonunion. The main goal of this study was to find out how CT scanning and plain radiographs are useful in the assessment of scaphoid union.

2. Methods

This study was approved by the Institutional Review Board of our institute, and the patients provided informed consent for using their medical data for publication. Between 2016 and 2018, the patients, who were referred to our center with a scaphoid nonunion, were identified. The patients were included if they were treated with the operation and had both plain radiograph and CT scanning conducted as a part of their follow-up. Those who were treated conservatively and those who had either CT images or plain radiograph were excluded from the study. Also, the patients, who did not have a union in the plain radiographs, were excluded from the study.

The surgical treatment included open reduction, illiac crest bone graft, and K-wire fixation as previously described (Figure 1) [11]. The clinical and demographic characteristics of the patients were extracted from their medical files. The healing of scaphoid nonunion was assessed on both CT images and plain radiographs by two different observers, who were fellowship-trained hand surgeons. The union was graded as healed or non-healed. In case the grading of two observers did not match, a third observer would be asked to help. The case would be excluded from the study if no consensus was reached regarding the union on either CT or radiograph. All the radiographs and CT scanning were performed in the same center and with the same machine.

Plain radiographs of the wrist, including anteroposterior and lateral views, were taken conventionally for each patient. The CT assessment was performed on 3D CT images. For this purpose, the union was investigated in at least three coronal and two sagittal CT sections.

Statistical analysis

The statistical evaluation of the data was performed in SPSS V. 16. The results of descriptive statistics were presented as Mean±SD or number and percentage. The union on CT scans and plain radiographs were compared, using a McNemar's test. A P-value of less than 0.05 was considered significant.

3. Results

A total of 25 patients, who underwent the operation for the treatment of scaphoid nonunion, were included in this study. The Mean±SD age of the patients was 29.1±6.8 years (range: 19-45 years). All the patients were male. The Mean±SD time interval from injury to operation was 36.4±54.3 months (range: 4-240 months). Table 1 presents the clinical and radiographic characteristics of the patients.

The Mean±SD time interval from operation to imaging was 6.5±2.5 months (range: 4-13 months). Based on the plain radiographs, the scaphoid union was obtained in all patients. Based on the CT evaluation, the scaphoid union was seen in 23(92%) cases. Accordingly, CT scans and plain radiographs were concordant in 23 cases and discordant in two cases. This difference

Table 1. Clinical and demographic characteristics of the patients with scaphoid nonunion (n=25)

Variable		Mean±SD/ No. (%)
		Scaphoid Nonunion Patients
Age (y)		29.1±6.8
Gender	Male	25(100)
	Female	0(0)
Hand dominancy	Dominant	12(48)
	Non-dominant	13(52)
The interval from the injury to the operation (mon)		36.4±54.3
The interval from the operation to the imaging (mon)		6.5±2.5
Union on plain radiograph	Yes	25(100)
	No	0(0)
Union on CT images	Yes	23(92)
	No	2(8)

was not statistically significant (P=0.5). Figure 2 shows the postoperative plain radiograph and CT scan of a case, who was identified with the scaphoid union in the plain radiograph, whereas union was not achieved in the corresponding CT image.

4. Discussion

The determination of proper healing is an essential component of the assessment of scaphoid fracture and nonunion. The radiographic monitoring of the healing progress of scaphoid is often necessary to prevent subsequent complications. Although plain radiographs are the most commonly used imaging modalities, they are not without pitfalls. Studies have revealed poor reliability of plain radiographs in the assessment of scaphoid fracture union [10]; thus, other imaging modalities such as CT scan and MRI have been suggested for this purpose [8].

In this study, we aimed to assess the differences between plain radiographs and CT images in checking the scaphoid union. Based on the results of the present

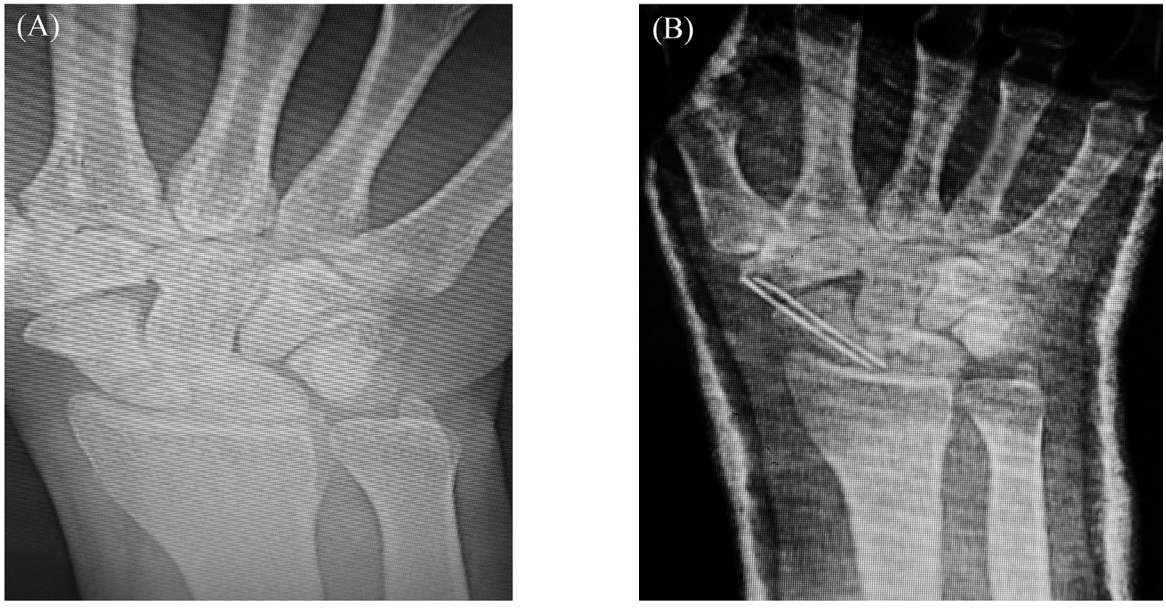

Figure 1. Anteroposterior radiograph of a scaphoid nonunion, treated with open reduction, illiac crest bone graft, and k-wire fixation
A: Preoperative; B: Postoperative

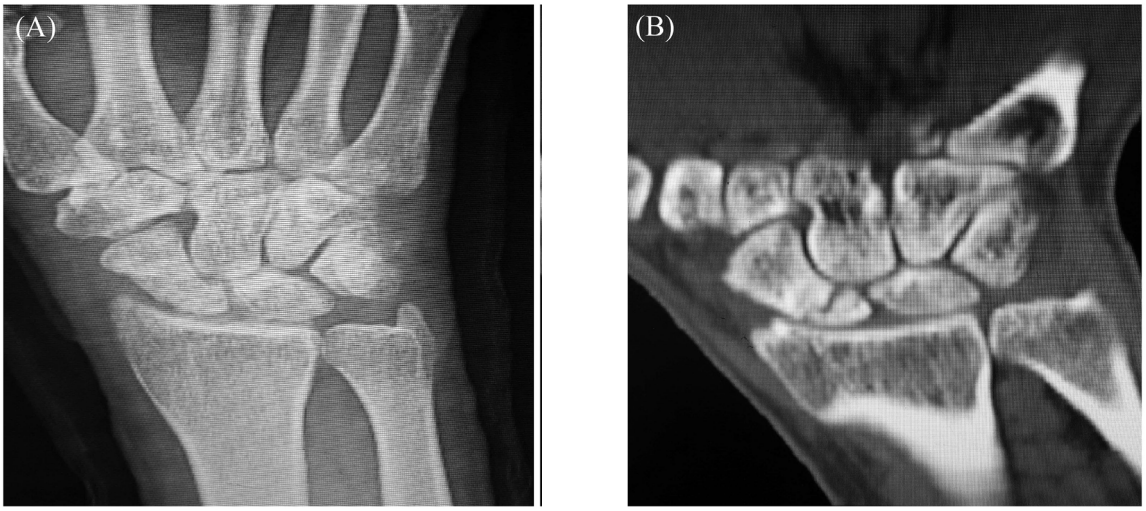

Figure 2. Plain radiograph and CT scan
A: Compelete union of scaphoid four months after the surgery; B: Concurrent CT scan showing the non- united scaphoid

study, a remarkable agreement was observed between plain radiographs and CT images so that in 23 out of 25 cases, both radiographs and CT scans revealed complete scaphoid union. Even so, in a subset of patients (2 out of 23 cases) the result of plain radiographs and CT scan was inconsistent so that a union was observed in plain radiographs, but not in CT scans.

Grewal et al. examined the inter-observer reliability of CT scans for quantifying scaphoid union. For this purpose, four blinded observers reviewed CT scans of 50 scaphoid fractures that were treated conservatively. Each reviewer reported the mean percentage of union and the weighted mean percentage of the union and then the inter-observer reliability of scores was assessed. The results revealed high inter-rater reliability among the observers, suggesting CT as a reliable method for the evaluation of scaphoid union [12].

Hannemann et al. examined the reliability and validity of scaphoid union assessment, using a multiplanar reconstruction CT scanning randomized at 6, 12, and 24 weeks after injury. For this purpose, three observers reviewed 44 sets of CT scans of 44 non-operatively treated scaphoid waist fractures. The inter-observer agreement was moderate (kappa value =0.576). The average sensitivity and specificity of CT for determining scaphoid union following fracture were (73%) and (80%), respectively [13].

Buijze et al. aimed at determining the inter-observer agreement CT scans for determining the union of scaphoid fractures. For this purpose, 59 orthopedic and trauma surgeons rated the union of a set of 30 sagittal CT scans from 30 scaphoid fractures. A substantial inter-observer agreement was found between the raters. The average sensitivity, specificity, and accuracy of sagittal CT scans for determining the union of scaphoid fracture were (78%), (96%), and (84%), respectively. The positive and negative predictive values of a diagnosis of the union were 0.99 and 0.41, respectively. They concluded that CT scans were reliable for determining the union of scaphoid fracture, but not for ruling out the nonunion of scaphoid fractures six to ten weeks after injury [14].

Dias et al. evaluated the inter-observer agreement and reproducibility of plain radiographs in the diagnosis of the union of scaphoid fractures on films taken 12 weeks after injury. Eight senior observers reviewed 20 sets of radiographs on two occasions with a two month interval. A poor agreement was found regarding the formation of trabeculae and sclerosis, as well as the vascularity of the proximal part of the scaphoid. Moreover, the agreement on union was poor. They concluded that plain radiographs obtained 12 weeks after the scaphoid fracture was not reliable and reproducible enough for detecting evidence of healing [10].

Reviewing the literature regarding the role of CT scan and plain radiographs in the evaluation of scaphoid union reveals that CT was more reliable and accurate than plain radiographs in the assessment of scaphoid union. However, the comparison of CT and plain radiographs in the assessment of scaphoid union has been less investigated.

Hackney performed an operation to compare CT scans and plain radiographs for the assessment of scaphoid fracture healing after the operation. He retrospectively

collected the data of 16 patients with scaphoid fractures, who were treated surgically and had both plain film and CT imaging as a part of their follow-up. Two observers (hand surgeons) assessed the images and graded as healed or non-healed. In 12 cases, the CT and plain radiographs were consistent regarding the healing of scaphoid. In three cases that were treated for the repair of scaphoid nonunion, CT could detect the radiographic signs of healing, whereas plain radiographs were unable. They concluded that in cases involving surgical repair of nonunion, CT was a superior imaging modality in the detection of subtle radiographic signs of healing before the appearance of such signs on plain film [15].

Following the study of Hackney, the results of the current study suggest the superiority of CT scanning in the detection of the union in patients, who underwent the operation for the treatment of scaphoid nonunion. In contrast to the study of Hackney, we identified two patients, in whom the scaphoid union was observed in plain radiographs, whereas the CT scans revealed the scaphoid nonunion. As this difference was not statistically significant, plain radiographs could still be performed as the primary choice of imaging in the evaluation of scaphoid union in these patients. However, in the patients, for whom plain radiographs cannot provide a clear-cut answer for the union status, a complementary CT scanning could be helpful.

The main limitation of this study was the small number of cases that might have adversely affected the power of statistical analysis. Thus, future investigations with a larger sample size are required to understand better the significance of CT scanning in the evaluation of scaphoid union.

5. Conclusion

In a subset of patients, who undergo the operation for the treatment of scaphoid nonunion, a disagreement might exist between CT scans and plain radiographs regarding the healing of scaphoid. In this respect, a union might be seen in the plain radiographs, but not in the CT scan. As this entails a small number of patients, the plain radiographs could still be used as the imaging modality of choice for the evaluation of scaphoid union in these patients. However, if union status is not recognizable on plain radiographs, a complementary CT could be obtained to attain a consensus.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of our institute (Code: 372, 13 may 2019).

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Authors' contributions

All authors contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interests.

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