Original Article

Bull Emerg Trauma 2023;11(4):173-177.

Bulletin of Emergency And Trauma

Evaluation of Various Fixation Methods in Acute Scapholunate Dissociation, A Finite Element Study

***Mohammad Amin Mahdiyar*[1], *Hamid Namazi*[1], *Hussein Malekjamshidi*[1*], *Mohammad Taghi Karimi*[2]**

[1]*Joint and Bone Research Center, Shiraz University of Medical Sciences, Shiraz, Iran*
[2]*Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran*

***Corresponding author:** Mohammad Taghi Karimi*
Address: Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran; **Tel:** +98 71 36685245;
e-mail: Mt_Karimi@Sums.ac.ir

Received: October 4, 2023
Revised: October 28, 2023
Accepted: November 8, 2023

ABSTRACT

Objective: This study aimed to compare the outcomes of fixing scapholunate with pins and screws in parallel, convergent, and divergent orientations.
Materials and Methods: In this computer simulation study, the CT scan images of a healthy subject were used to construct a 3D model of the wrist joint using MIMICS software. The imposed force to scaphoid and 3D model lunate bones, as well as the scapholunate angle and distance, were compared in different surgical techniques using parallel, divergent, and convergent pins and screws.
Results: In the absence of external force, the imposed stress applied to the scaphoid and lunate bones in cases of parallel pins and screws were 7.5MPa, 5.08MPa (pins), 1.134MPa, and 1.151MPa (screws), and 10.90MPa, 10.90MPa (pins), 9.7MPa, and 34.1MPa (screws) for 50N flexion force. The imposed stress in this approach is significantly lower compared to other interventions. Better outcomes were seen regarding scapholunate angle and scapholunate distance in using parallel pins or screws as well.
Conclusion: In conclusion, implementing parallel pins and screws for scapholunate fixation had better results in terms of achieving carpal stability in scapholunate dissociation. However, fixation with pins and screws showed a statistically significant difference. Furthermore, a wide range of motion exercises with no additional forces can be used in the rehabilitation of patients undergoing this surgery.

Keywords: Scapholunate dissociation; Scapholunate fixation; Scaphoid bone; Lunate bone; Orthopedic fixation device.

Please cite this paper as:
Mahdiyar MA, Namazi H, Malekjamshidi H, Karimi MT. Evaluation of Various Fixation Methods in Acute Scapholunate Dissociation, A Finite Element Study. *Bull Emerg Trauma*. 2023;11(4):173-177. doi: 10.30476/BEAT.2023.100425.1469.

Introduction

Scapholunate dissociations, the most prevalent type of carpal instabilities, occur as a result of scapholunate ligamentous injury in the process of excessive load to the wrist while the wrist is in extension and ulnar deviation [1]. Scapholunate dissociations are seen in 5% of wrist sprains and 13.4% of fractures in the distal end of the radius [2, 3]. This condition is often presented as tenderness in the anatomical snuffbox, tenderness over the dorsoradial aspect of the wrist, edema, and restricted range of motion in the wrist with no evidence of scaphoid fracture in imaging studies [4].

Geissler *et al.,* recommended conservative and surgical approaches for the treatment of scapholunate dissociation based on the severity of the condition [5]. Inappropriate management of scapholunate dissociation might result in arthritis and wrist immobility [3]. The method of surgeries ranges from arthroscopic debridement in cases of incomplete scapholunate ligament injury to more invasive procedures such as scapholunate arthrodesis in complete scapholunate ligament injury with irreducible malalignment, and even total wrist arthrodesis or proximal row carpectomy in cases of cartilage damage [6].

After performing open or arthroscopic reduction of the dissociation, the scaphoid and lunate bones can be fused using pins or screws of varying angles. However, no comprehensive study has compared the pin- and screw-fixation of the scapholunate joint, in terms of postoperative angle, range of motion, and the forces imposed on scaphoid and lunate bones in various positions. In the light of previously mentioned evidence, we aimed to compare pins and screws, as well as the method of their implementation in scapholunate arthrodesis.

Materials and Methods

In this cross-sectional modeling study, the CT scan images of a healthy subject were used to generate a three-dimensional model of the wrist joint using Materialise MIMICS software (developed by Materialize NV, Leuven, Belgium) version 19.0. A wrist CT scan was obtained with 1.5° ulnar deviation, 1.5 mm slice thickness, and 0.98 mm slice interval. The CT scan images were imported into MIMICS version 19.0, and three-dimensional models of the wrists were made as follows:

1. Determining the threshold and creating a mask based on the Hounsfield units
2. Editing the created masks
3. Using "region growing" and selecting the connected voxels for the segmentation of separate parts
4. Creating three-dimensional models based on the generated region mask
5. Using the re-mesh option to convert files into a format compatible with 3-matic software

The model was assessed regarding the stress imposed on scaphoid and lunate bones, as well as scapholunate angle, and distance in its normal configuration with intact scapholunate ligament (SLL), and completely torn SLL. Afterward, six different models were created utilizing A) parallel pins B) convergent pins C) divergent pins D) parallel screws E) convergent screws, and F) divergent screws. Then, the joint fixation parameters such as the force imposed on scaphoid and lunate bones, scapholunate angle, and scapholunate distance in no force condition, and in a 50N external force condition were measured (Figure 1).

All of the models were created in 3Mat software. The pins and screws were inserted in this software the same as procedures done in real conditions. The models were exported to Abaqus software. The bones were aligned with each other, the same as a normal wrist. In this software, the material properties were applied to the bone. The material properties were obtained from the literature. All of the supportive ligaments of the wrist joint structure were added to the models as spring elements. The ligament stiffness was obtained from the literature.

The models were run to move in extension mode. The force of wrist joint extensors was obtained from the previous publications of the authors [7]. In Abaqus software, the forces of wrist joint extensors were applied to the models under two different conditions: without external force (external weight equal to zero), and with external force (external weight equal to 50 N).

It is emphasized that the models run from a neutral position to an extension. Some parameters such as the distance between the scaphoid and lunate, and the angle of these bones were evaluated in this study. These parameters were the same as those used by clinicians to diagnose scaphoid bone instability.

The outcomes of each surgical method were then compared with the natural and pathologic conditions.

Results

A 3D model of a skeletally mature male wrist was made by the use of MIMICS software, and SLL was cut in the model. In this model, scapholunate dissociation was fixed by various surgical techniques, including A) fixation with parallel pin, B) fixation with divergent pins, C) fixation with convergent pins, D) fixation with parallel screws, E) fixation with divergent screws, and F) fixation with convergent screws (figure 1). each model was contrasted with normal scapholunate and completely torn SLL. The comparison took place in a no-force condition. The results are summarized in Table 1.

In the case of the stress imposed on scaphoid bone in no force condition, fixation with parallel screws relieved most of the strain (1.134 MPa in the case of parallel screws vs. 3.64 MPa in torn SLL); however, a completely ruptured SLL was the closest to the normal joint (3.94 MPa). With an external force, the force exerted on the lunate bone was closest to the normal joint in fixation with parallel pins (5.08 Mpa in parallel ins vs 6.1 Mpa in the normal joint). In cases of Fixation with screws, the imposed stress to the lunate bone was 1.55, 1.8, and 2.7 Mpa in cases of parallel, divergent, and convergent screws, respectively. In the no-force condition, fixation with parallel pins (5.08 MPa) also reduced the force exerted on the lunate bone.

By measuring the scapholunate angle after fixation in the absence of external force condition, fixation with parallel and divergent pins (67.0° and 63.0°) was the most similar to the normal joint (62.0°).

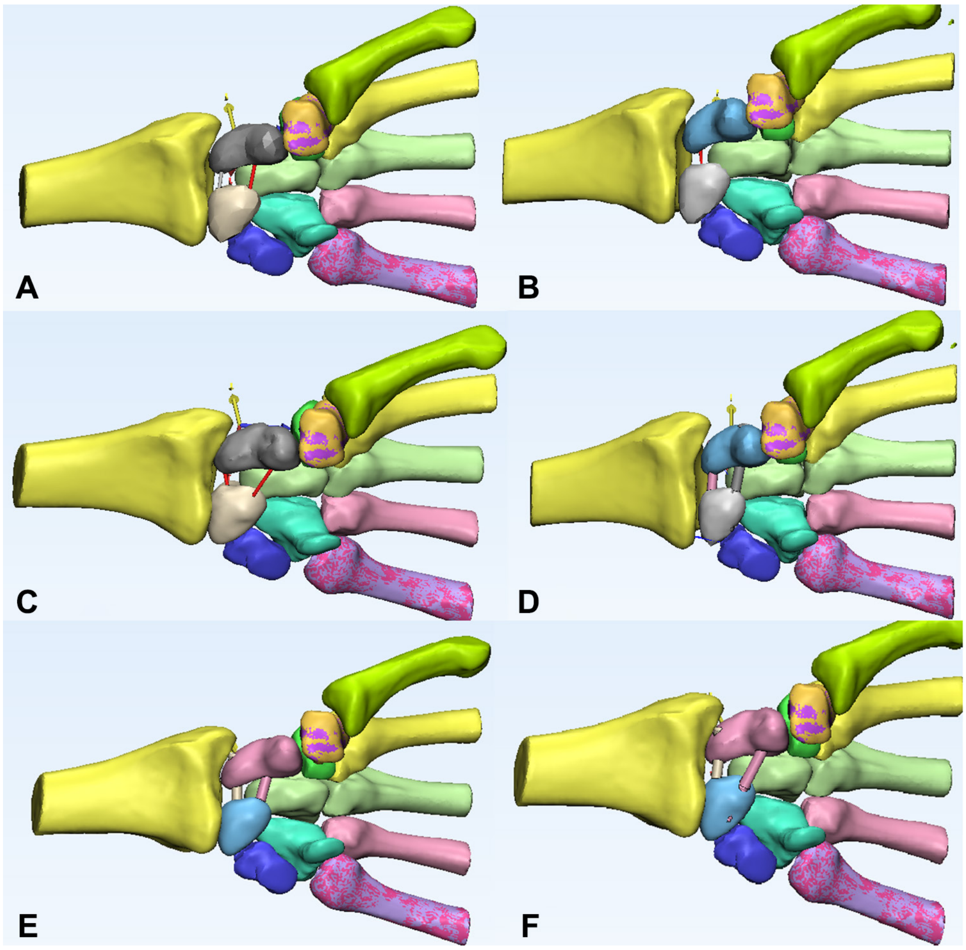

Fig. 1. Various methods of fixation used in this study: **A)** fixation with parallel pins, **B)** fixation with divergent pins, **C)** fixation with convergent pins, **D)** fixation with parallel screws, **E)** fixation with divergent screws, and **F)** fixation with convergent screws.

Moreover, regarding the distance between the scaphoid and lunate bones, in the no-force condition, fixation with pins brings the bones closer to each other (less than 3mm). However, this distance increases after fixation with screws (3.54, 3.52, and 3.20 mm in the cases of parallel, divergent, and convergent screws, respectively), even more than a completely torn scapholunate ligament (3.10 mm).

Afterward, 50N external force was applied to the model and ran from the neutral position to the extension. In this position, the same parameters were assessed. The results are presented in Table 2.

When 50 N external force was exerted on the joint, divergent screws were preferable in terms of the stress imposed on the scaphoid bone (3.69 Mpa), while convergent and divergent pins were very poor options as they imposed great stress on the scaphoid bone (225 and 477 MPa, respectively). Although all of the surgical options increased the stress on the lunate bone when the joint was subjected to a 50 N external force, fixation with convergent screws was most consistent with the biomechanics of the normal joint in terms of the force imposed on the lunate bone (6.19 MPa in convergent screws vs 2.82 MPa in the normal joint). Fixation with parallel pins (10.9 MPa) was also a viable method.

In the 50N external force, parallel pins (67.3°) had the highest resemblance to the normal scapholunate joint (63.0°) regarding scapholunate angle. In the case of 50 N external force, fixation with pins decreased the scapholunate distance (3.08, 2.32, and 2.86 mm in cases of parallel, divergent, and convergent pins, respectively), and fixation with screws increased the distance (3.94, 3.22, and 4.12 mm in cases of parallel, divergent, and convergent screws, respectively). However, less distance was noted in fixation with divergent screws compared to a completely torn SLL (3.40 mm).

As shown in Tables 1 and 2, patients undergoing scapholunate fixation using parallel pins and screws had better outcomes than other surgical options, especially when the joint was subjected to 50N external force.

Discussion

In this study, we evaluated various surgical models with scapholunate dissociation who had undergone scapholunate fixation using pins or screws. We found that convergent and divergent pins were inappropriate to use in cases of stress applied to the scaphoid and lunate bones due to the high stress applied to these bones with and without external pressures. For screws, the parallel configuration was superior in a

Table 1. Comparison of the surgical approaches in fixation of scapholunate dissociation in no force condition

Variable	Stress to scaphoid (MPa)	Stress to lunate (Mpa)	Scapholunate angle (degree)	Distance (mm)
Normal	3.94	6.1	62.0	3.28
Torn SLL	3.68	3.68	80.0	3.10
Parallel pins	7.5	5.08	67.0	2.80
Divergent pins	32	65.7	63.0	2.88
Convergent pins	98.2	73.6	77.4	2.80
Parallel screws	1.134	1.55	75.7	3.54
Divergent screws	1.8	1.8	71.4	3.52
Convergent screws	2.7	2.7	78.5	3.20

Table 2. Comparison of the fixation methods in scapholunate dissociation in external force condition

Variable	Stress to scaphoid (Mpa)	Stress to lunate (Mpa)	Scapholunate angle (degree)	Distance (mm)
Normal	2.82	2.82	63.0	3.29
Torn SLL	4.82	6.87	85.3	3.40
Parallel pins	10.90	10.9	67.3	3.08
Divergent pins	477	381.7	70.6	2.32
Convergent pins	225	389.2	83.0	2.86
Parallel screws	9.7	34.1	72.4	3.94
Divergent screws	3.69	7.43	80.5	3.22
Convergent screws	6.05	6.19	79.6	4.12

neutral condition (no external force applied), while divergent screws were optimal in minimizing the stress to the scaphoid and lunate bones when external force was applied. When the scapholunate angle was being considered, divergent screws increased the angle in 50N external force, which should be avoided. Additionally, in this position, convergent screws increased the scapholunate distance, leading to greater joint instability. Consequently, parallel screws and pins are recommended in cases with scapholunate dissociation. No previous study has evaluated the stability of the scapholunate joint in such different surgical approaches. Thus, for the first time, this study thoroughly assessed the configuration of orthopedic instruments in the fixation of this joint.

Mathoulin *et al.,* conducted a review and declared that the standard of care in scapholunate dissociation has yet to be discussed [8]. However, they found that management of this condition has undergone numerous adjustments throughout the previous decades. The initial management consisted of open reduction and ligament restoration using the Extensor Carpi Radialis Longus tendon. With the advent of various surgical techniques, arthroscopic management of scapholunate dissociation has been routinely performed in certain centers. However, since arthroscopic interventions need highly competent surgeons, and the equipment is not widely available, open surgical approaches require special consideration.

Jakobietz and colleagues conducted a study and used Kirschner wires fixation on five cadavers with scapholunate dissociation [9]. Fixation with pins and screws in our study seemed to be more effective in minimizing dorsal intercalated segmental instability. Therefore, fixation with pins and screws seems to be more appropriate in this matter.

In a case series, Cognet *et al.,* conducted scapholunate fixation with screws following arthroscopic debridement in seven patients with chronic scapholunate instability [10]. In the follow-up of the patients, they found that all of the patients experienced joint destruction after a maximum of five months. They concluded that such a procedure should no longer be carried out. However, the present study did not have enough information about the patient's long-term follow-up. Moreover, since little evidence is available in this regard, further studies are required to assess the long-term effect of such procedures.

In this study, we compared the efficacy of scapholunate fixation with pins and screws. Although the method used in this article has been used to evaluate the safety and the response to treatment for other carpal problems [11], no previous study applied 3D computer models to evaluate the efficacy of various surgical methods in the treatment of scapholunate dissociation, and this study is the first research which achieved this goal. To better define the standard of treatment in scapholunate dissociation, further studies comparing other surgical methods should be conducted.

Due to the paucity of literature, a proper rehabilitative approach for scapholunate dissociation is not well established [12]. Current evidence proposes exercises emphasizing enhancing joint proprioception and stability by tossing and catching a ball or bouncing a tennis ball on a racket [13]. Liew et al., performed a systematic review of the timing of the patients' return to work and exercise [14]. They reported that patients who had surgical interventions addressing scapholunate dissociation had a high rate of return to work and activity. In our study, we found that following scapholunate fixation with pins or screws, range of motion exercises with no imposed force can be remarkably beneficial for scapholunate angle and joint stability.

Consequently, patients undergoing these procedures should be instructed to perform a range of motion exercises after the wound has healed appropriately, and no long-term casting is required in these patients. Having a range of motion exercises will also decrease joint stiffness following the surgery.

There are some limitations associated with this study. The main limitation was that this was a computer simulation study. Therefore, the findings of this study should be used with caution. It is recommended that the same study should be repeated using the same procedure and with a greater number of subjects in the future.

In conclusion, concerning the scapholunate angle and the imposed stress on scaphoid and lunate bones, scapholunate fixation using parallel pins and screws was preferable to scapholunate fixation with convergent or divergent pins and screws in patients with scapholunate dissociation.

Declaration

Ethics approval and consent to participate: This study was approved by the Ethics Committee in Biomedical Studies of Shiraz University of Medical Sciences (code: IR.SUMS.MED.REC.1398.410). The CT image of a healthy person was randomly obtained from the PACS system.

Conflicts of Interest: The authors declared no conflicts of interest.

Acknowledgment: None.

Funding: None declared.

Authors' Contribution: MAM, HM, and HN contributed to the design and implementation of the research, the results, and the writing of the manuscript. MTK wrote the methods and material and did the analysis. All authors have read and approved the final manuscript and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Garg BK, Dave H. Scapholunate dissociation with ulnar impaction: a case with review of literature. *Journal of Orthopaedic Case Reports*. 2020;**10**(3):76.
2. Chennagiri R, Lindau T. Assessment of scapholunate instability and review of evidence for management in the absence of arthritis. *Journal of Hand Surgery (European Volume)*. 2013;**38**(7):727-38.
3. Andersson JK. Treatment of scapholunate ligament injury: current concepts. *EFORT Open reviews*. 2017;**2**(9):382-93.
4. Stevenson M, Levis JT. Image diagnosis: scapholunate dissociation. *The Permanente Journal*. 2019;**23**.
5. Geissler WB. Arthroscopic management of scapholunate instability. *Journal of wrist surgery*. 2013;**2**(02):129-35.
6. Kitay A, Wolfe SW. Scapholunate Instability: Current Concepts in Diagnosis and Management. *The Journal of Hand Surgery*. 2012;**37**(10):2175-96.
7. Vahabi Z, Mokhtarian A, Karimi MT, Jahanshah F, Arefi R. Design and Control of an Active Wrist Orthosis for Rehabilitation. *Journal of Rehabilitation Sciences & Research*. 2021;**8**(1):46-50.
8. Mathoulin C, Merlini L, Taleb C. Scapholunate injuries: challenging existing dogmas in anatomy and surgical techniques. *Journal of Hand Surgery (European Volume)*. 2021;**46**(1):5-13.
9. Jakubietz MG, Zahn R, Gruenert JG, Waschke J, Meffert RH, Jakubietz RG. Kirschner wire fixations for scapholunate dissociation: a cadaveric, biomechanical study. *Journal of Orthopaedic Surgery*. 2012;**20**(2):224-9.
10. Cognet JM, Levadoux M, Martinache X. The use of screws in the treatment of scapholunate instability. *J Hand Surg Eur Vol*. 2011;**36**(8):690-3.
11. Öten E, Uğur L. 3D volumetric evaluation of the diagnosis and severity of carpal tunnel syndrome using MRI. *Journal of Clinical Neuroscience*. 2022;**97**:82-6.
12. Melone CP, Polatsch DB, Flink G, Horak B, Beldner S. Scapholunate interosseous ligament disruption in professional basketball players: treatment by direct repair and dorsal ligamentoplasty. *Hand clinics*. 2012;**28**(3):253-60.
13. Wolff AL, Wolfe SW. Rehabilitation for scapholunate injury: application of scientific and clinical evidence to practice. *Journal of Hand Therapy*. 2016;**29**(2):146-53.
14. Liew MY, Dingle LA, Semple A, Rust PA. Return to sport or work following surgical management of scapholunate ligament injury: a systematic review. *British Medical Bulletin*. 2023;**145**(1):30-44.